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R. A. F. Official Photograph

REPRESENTATIVE RIGID AND NON-RIGID TYPES OF BRITISH DIRIGIBLES CRUISING AMONG THE CLOUDS. (See page 405)

The Mechanics of Earthquakes*

Recent Views with Regard to the Nature of Seismic Disturbances

By Carlo Somigliana, University of Turin

It cannot be said that there is any general mechanical theory at the present time concerning the movements produced by the vibrations of the ground, both upon the surface and in the interior of our planet; although increasingly exact methods of observation have revealed to us both their general properties and their more minute detail.

We say that we possess a mechanical theory of a phenomenon when we are able to construct an ideal model of it comprised within a certain system of finite or differential equations, which determine mathematically the laws of variations of the measurable quantities by which the phenomenon is characterized. In such a case it is possible to make a comparison between the data observed and the theory, thus determining the value of the latter. A typical and very marvellous example of this is the celestial mechanics which comprises within a single law, that of Newton, and in a single system of differential equations deduced therefrom, the laws of movement which govern not only the solar system, but very probably the entire universe.

In the case of seismic movements certain theories of a mechanical character which represent, frequently with great precision, certain features of the phenomenon are generally accepted. But these views do not always agree with each other and, furthermore, they do not possess a common origin about which they can be grouped in such a manner that the problem of the representation of seismic waves can be reduced to a single problem of mathematical analysis, as is the case for many other questions in physics.

As a matter of fact if we consider the subject from a general point of view, it is possible to regard seismic movements, at least in a first approximation, as vibrations of a free sphere, such as our own globe may be represented to be. But the laws of the vibrations of such a sphere have long been studied both with remarkable precision and with regard to their general application, and have been classified and arranged in groups according to definite properties, thanks especially to the researches of Mr. H. Lamb. However, it sometimes occurs in the mathematical treatment of problems in physics that the highly general character of the solution prevents its application to the special case in hand. Furthermore, in the present question there are certain peculiar features which must be taken into account, e. g. the unknown heterogeneities of the interior of the Earth, which limit the value, as regards the seismic problem, of the general solutions, so admirable in themselves, of the problem of the waves in a free homogeneous sphere.

This is why research along these lines has followed an opposite path to a certain extent. Instead of seeking, in the general solutions already known, the special solutions best adapted to the representation of the observed facts, it has sought to make use of the simplest solutions known, attempting to arrive by means of these, at least approximately, at the ideal models, which form, as we have said, the supreme goal of the theory.

We shall attempt to give in these pages a brief summary of these attempts and their results. However, it is proper to first form an idea of the nature of the objects aimed at in theoretic seismology and of the importance with regard to the knowledge of the constitution of our planet which they may possess.

In the majority of physical theories the result aimed at by the investigator is the prediction of the phenomenon. The said prediction constitutes in itself the best confirmation of the theory. But it must be admitted that in the science of seismology absolutely correct prediction lies outside the scope of any theory whatever, no matter how perfect it may be. Seismic movements are phenomena which are produced spasmodically and which depend upon a very special class of circumstances which lie outside the possibility of direct control. These sudden tremors which pass over the surface of the earth are determined by ruptures of the internal equilibrium in localities of limited extent, and these ruptures are due to accidental causes of which we are ignorant. The researches made with the object of establishing in a general manner the frequency of earthquakes in time and in space, have thus far failed to enable us to formulate laws which would permit the making of predictions. The results attained belong to the domain of statistics or of probabilities and have no relation, furthermore, to the mechanical theory of the movement.

The importance of seismic mechanics is of a different nature. It teaches us, above all, to read and to interpret the data yielded by observation which would remain meaningless without the light thrown upon them by theoretic concepts. Seismic diagrams are writings which can be understood only by him who knows the language of mechanics. In the second place seismic mechanics enables us to deduce valuable indications with regard to the constitution of the interior of the Earth, of those vast, mysterious depths which we can have but little hope of penetrating directly by means of research at our disposal. It seems quite certain, in fact, that seismic vibrations penetrate to very great depths in the terrestrial mass, appearing afterwards upon the surface in various forms which are characterized by the special constitution of the strata they have traversed, just as a ray of light is modified in various ways by the transparent mediums through which it passes. The study of these modifications enables us to find our way back to their causes and thus to obtain certain ideas with regard to the peculiar physical properties of deep-lying terrestrial strata. It cannot be claimed, of course, that the analysis of seismic vibrations has led thus far to results at all comparable to those yielded by spectrum analysis with regard to the chemical constitution of the celestial bodies. But these first messages from the interior of the globe to reach us have already furnished valuable contributions to the study of the various hypotheses which have been propounded upon the subject of its internal constitution. It is true that we are able to observe upon the surface of the earth other phenomena which are necessarily connected with its constitution, such as the magnetic field, or the field of gravitation; but the deductions capable of being derived from these are not very extensive and it often happens that they have a purely global character and consequently fail to exhibit localized properties.

* * *

As said above, the simplest laws first made use of for the study of seismic waves are those concerning the propagation of plane waves, or of spherical, longitudinal, and transverse waves. If we conceive of a vibrating medium subdivided into a number of parallel planes like the pages of a book, and imagine each of these planes in itself to be subject to small periodical back and forth movements in the direction of their common normal, we shall have an idea of what is meant by a system of longitudinal plane waves. If, on the contrary, we represent each plane as sliding periodically upon itself we shall have the conception of movement by transverse plane waves. It is evident that in the second case the volume of any part whatever, separated in the vibrating medium by a cylindrical surface normal to the planes of the wave, will not perceptibly vary during the movement; just the opposite to this is true in the first case, in which the height of each cylinder is subject to continual variations. Thus the waves of the first class will be waves of *expansion* [dilation] while the others will be called *equivoluminal*. If instead of a series of parallel planes we consider a series of concentric spheres, we may then have two classes of spherical waves, in one of which the spheres undergo periodic changes of radius while vibrating, while the others slide upon themselves. Thus we may say again that spherical waves are either expansional or equivoluminal. It may be proved also that in all cases the movement is propagated along the normal to the surface of the wave; this is why the movement of vibration is parallel to the direction of propagation in one case, while in the other it is perpendicular to it. For this reason the waves of expansion are called *longitudinal*, while equivoluminal waves are called *transverse*. The speed of propagation of the first kind in every uniform elastic medium is always greater than that of the second kind.

But in the seismic diagrams which began to be systematically collected in the last decades of the last century, two phases were at once distinguished: the first consisting of very small and irregular movements, to which the name of *preliminary tremors* has been given, and the much ampler and more regular ones which follow, and to which great catastrophes are due. English seismologists call this second phase the *main shock*.

The first idea which presented itself by way of an attempt at mechanical explanation of the phenomenon was the comparing of the preliminary tremors to the more rapid longitudinal waves and the ample vibrations which succeed these to the slower transverse waves. But there are various special features of the observed data which fail to agree with this concept.

During this time there appeared in 1885 a remarkable study by Lord Rayleigh announcing the discovery by purely theoretical methods of a new class of waves, with regard to which it is possible to demonstrate the absolute possibility of their propagation in a ground plane of indefinite width and extent. These waves are characterized by the property of becoming very rapidly extinguished beneath the surface of the ground; for this reason they have been called *superficial*. It is a well-known fact in acoustics that the form of a vibrating body is of fundamental importance with respect to the possible vibrations of the said body, and this is why it would be incorrect to assume, as was done at first, the possibility of autonomous longitudinal or transverse plane waves in a body of finite dimensions, such as our globe. The indefinite ground plane in which Rayleigh's waves propagate themselves, is very far from being an exact model of the terrestrial sphere, but in a primary approximation, or, at any rate, by way of obtaining a primary qualitative representation of the facts, it may be accepted as being true within certain limits. It must be admitted also that Rayleigh's waves possess certain special characteristics which has caused them to be of great value in the science of seismology. They result from the superposition of transverse waves and waves of expansion, and possess no actual wave planes; they can also be called *rectilinear* waves, since the vibrating elements are not planes or spheres but straight lines. Furthermore, they possess the fundamental property of propagating themselves with a constant speed along the surface of the ground.

It was R. D. Oldham who in 1900, after a very attentive and systematic study of the numerous data yielded by observation, proposed taking Rayleigh's waves as a mechanical representation of the waves called *long* waves in the final and principal phase of the seismic shock. From this study he concluded that it is necessary to divide the preliminary tremors into two phases which he considers respectively comparable to the two series of longitudinal and transverse waves emanating from the hypocenter, or internal point of origin of the earthquake. These two series of waves must necessarily be distinct from each other because of the different rate of speed which they possess. They are called respectively primary waves and secondary waves. Thus we have altogether three groups of waves: the *primary* waves, which are longitudinal; the *secondary* waves, which are transverse; and the waves of Rayleigh, or *long* waves.

These hypotheses are corroborated by various facts. We may assume, indeed, that the phenomenon takes place in the following manner: The expansional waves and the equivoluminal waves start from the hypocenter at their respective rates of speed and reach the surface of the earth successively. Neither of these categories of waves can remain separate after the movement has reached the surface; they mingle, therefore, to form a single system, which is the system known as the waves of Rayleigh. The two first groups of waves, expansional and equivoluminal, thus represent in their pure state a brief initial phase of the phenomenon; the waves of the third group, which have been compared to Rayleigh's waves, represent the succeeding phase, which can also be considered, up to a certain point, as the ruling phase [phase de régime]. Observation has proved positively that the traces of these waves can be discovered a number of hours after the beginning of the shock; and they can be perceived at the same observation station, either as coming directly from the epi-center by the shortest surface path, or as coming by way of the arc of the maximum circle which does not contain the said observation station, or else their return path after having traversed the whole extent of the terrestrial maximum circle which passes through the epi-center and the observation station.

This concept has been confirmed in a remarkable manner by figures. Let us take V_1 and V_2 as representing the average value of the speed of propagation of longitudinal and transverse waves; $V_1 = 7.17$ and $V_2 = 4.01$, the values given by Galitzin in his classic

*Translated for the Scientific American Supplement from *Scientia* (Bologna).

work, *Treatise on Seismology*, the unit of length being the kilometer, and the unit of time being the second; the proportion they bear to each other may be expressed as follows $V_1 : V_2 = 1.788$.

But the theory of elasticity enables us to deduce from this ratio the value of what is called Poisson's coefficient σ the elastic constant which is characteristic of the matter of which the vibrating medium is composed. Taking as a base the preceding value of the ratio $V_1 : V_2$ we find that $\sigma = 0.27$, a value which is very close to the average value 0.25 which experiment has caused us to assign to the materials of which the superficial crust of the Earth is composed.

Furthermore, the theory of Rayleigh's waves assigns the value V_3 to the speed of propagation of the said waves; and this value V_3 depends upon V_2, according to the ratio $V_3 = 0.9194 V_2$.

Taking the figures mentioned above, 4.01 as the value of V_2 we find that $V_3 = 3.69$, a value which is very close to the values which have been determined by experiment as those of the rate of prapagation of the third group of waves, i. e. the long waves.

More recent observations and calculations have slightly modified the average values of the rates of speed quoted above, but without substantially altering the admirable agreement between theory and experiment exhibited in the figures quoted.

The classification of seismic waves into the three groups mentioned above corresponds to a first examination of seismograms. A closer analysis of the latter, and also certain theoretic studies of which we shall speak later, have led us to distinguish in these three fundamental groups of waves sub-groups to which special maximums of amplitude, of periods of vibration, and of rates of propagation correspond. The values deduced from observations made during the great earthquake at Messina in 1908 have given us rates of propagation for the group of long waves comprised between 3.2 and 4.7 kilometers per second, and by means of very close study Prof. Rizzo has been able to distinguish three sub-groups, whose rates of propagation are comprised respectively between 4.2 and 4.7 for the first group, 2.6 and 4.0 for the second group, and 3.2 and 3.5 for the third group.

Various hypotheses may be formulated to explain these facts. Prof. De Marchi has sought the explanation in a more general theory of Rayleigh's waves which propagate themselves in a plane stratum of limited thickness rather than in an infinite depth of ground [plutôt que dans un sol infiniment profond]. This is in accordance with modern views which regard the Earth as being formed of an internal nucleus which is mainly metallic in nature surrounded by a rocky envelope.

But it is possible, even without abandoning the initial concept of Lord Rayleigh, to give to the facts above mentioned, by means of a profounder study of the problem, an explanation which will not depart from the somewhat elementary class of ideas upon which the theories thus far propounded are based.

The determination of the rate of propagation of Rayleigh's waves at the surface of the ground depends upon an algebraic equation of the third degree, which in ordinary conditions has three real roots. The smallest of these roots gives the ratio 0.9194 which enables us, as we have seen, to deduce the rate of speed V_3 of Rayleigh's waves from the rate V_2 of the transverse waves. The two other roots are of no importance with respect to the problem stated by Rayleigh.

But if we examine from a general point of view the problem of the propagation of plane waves in an unlimited depth of ground, we find that it permits of three solutions, one of which is that of Rayleigh; this is a somewhat singular solution by reason of the fact that the wave planes are reduced to simple straight lines. The two others are composed of couples of ordinary wave planes, one longitudinal and the other transverse, whose directions of propagation in space are so inclined with respect to each other that their rate of propagation at the surface of the ground becomes identical. The rate of propagation of each of these couples is exactly determined by the two larger roots of the equation of the third degree which the first theory neglects. Thus the hypothesis appears plausible which explains the three sub-groups of long waves by assuming that they represent the three solutions of the problem of plane waves in the ground, in whose discovery the foregoing analysis was of assistance, and which comprise the result obtained by Lord Rayleigh. This view is supported by figures. The theoretical value of the ratio of the rates of propagation of the first and the second sub-groups is found to be 1:12; the calculations made by Prof. Rizzo in the Messina earthquake indicate that this ratio is comprised between 1: 12 and 1: 20, these figures being the result of 22 determinations. This explains the plausibility of the hypothesis that the three systems of waves indicated by Rayleigh's problem actually exist in the group of long waves if we take into consideration the sub-groups discovered by observation.

Another hypothesis of wider scope may be set up to interpret the results of the preceding analysis, it consists in the comparison of the three fundamental systems of primary, secondary, and long waves to the three systems of associated wave-couples which are obtained as solutions of the problem of plane waves in the ground. In order to make this theory agree with experimental results we must assume that Poisson's ratio has a different value for the planet Earth from that which it possesses for the superficial materials which form the subject of our direct examination—an assumption which is entirely permissible. But if we calculate this value we find that $\sigma = -0.25$, i. e., a negative value; but while the laws of mechanics do not exclude the possibility of this, since it is contained within the limits assigned by the said laws to this coefficent, it has so far not been found by experiment to belong to any known body.

This second hypothesis, which would have the advantage of uniting under a single concept and in a single analytical problem the general problem of seismic waves, and which encounters no difficulties of a mechanical nature, thus confronts numerical values which conform but poorly to known physical data. This leads us to prefer the first hypothesis.

* * *

The mechanical solutions of the seismic problem thus far examined are based upon mechanical concepts of the simplest sort and relate rather to an external representation than to an intrinsic explanation of the problem.

As a matter of fact the theories thus far examined consider a few special cases of vibration discovered by the authorities on mechanics and compare the said cases, in various fashion, with the different kinds of waves distinguished by observation. But from the physical point of view the phenomenon is a single one, and this separation into independent problems appears somewhat arbitrary.

Futhermore a complete theory ought to explain to us how the various classes of waves observed in a seismogram can be derived from a single cause of disturbance.

To Prof. Horace Lamb belongs the credit of having first attacked this problem, in 1904, with breadth in his mechanical concepts and genius in his methods of analysis. He made a study of the propagation, in an unlimited ground plane of the disturbance produced by a superficial impulse which he supposed to be located along a straight line or at a point. This disturbance is naturally propagated first as a rectilinear disturbance, and secondly in the form of concentric circles. The analytical basis of this solution is still Rayleigh's solution, but very ingeniously extended and amplified. The most remarkable result obtained by Lamb is to the effect that the movement which is propagated on the surface is characterized by three *salients*, [saillants] which travel respectively with the speed of longitudinal waves, transverse waves, and Rayleigh's waves. We thus obtain an exact reproduction by a synthetic method of the fundamental characteristics of the observed facts.

However, certain details of the representation are insufficient, e. g. these waves of Lamb are not periodic in character, and, like some of those considered above, they do not comprise vibratory displacements in a direction normal to that of propagation; yet such displacements do actually exist. This does not lessen their importance, however, which is all the more notable from the mechanical point of view, since they afford an explanation of the fundamental fact of the formation of the three waves, while other theories introduce this fact by way of a hypothesis (even though this may be justified by general considerations).

Following a very different class of ideas, Prof. A. E. H. Love of Oxford has come much nearer to the real nature of the observed facts in his penetrating study of numerous special problems connected with vibrations propagated in a homogeneous sphere or in its superficial strata, either in an indefinite ground plane or in one limited by another deep plane. The vibrations examined are harmonic, of arbitrary frequence, and correspond, therefore, to the vibratory character of seismograms.

Let us recall briefly some of the results obtained. In a homogeneous planet the action of the mutual gravitation of the masses which compose it causes no change in the laws of propagation of equivoluminal waves, laws which are obtained without taking gravity into consideration: expansional waves, on the contrary, are modified. These waves, in a similar case, cannot exist in the pure state, but are accompanied by a slight rotation of the vibrating particles. Moreover their rate of propagation is not constant, but varies in space, and depends furthermore upon the length of the wave; the shorter waves travel faster than the longer ones, and because of this there are dispersion phenomena. These results accord with the fact, observed in preliminary tremors, that the intervals between the successive maxima tend to constantly increase.

In conformity with the generally accepted hypothesis of the existence of a superficial terrestrial crust having physical properties notably different from those of the subjacent masses, Prof. Love studied the possibility of the propagation, in a plane stratum, of waves for which the horizontal component of the displacement would be either normal or parallel to the direction of propagation. And he demonstrated the possibility of these two types of waves when certain conditions are realized with regard to the physical constants of the stratum and of the subjacent mass. This enabled him to deduce certain interesting conclusions concerning the constitution of the seismic waves of the third phase, the long waves. According to this theory the latter are composed of two types of waves, each constituted by an aggregate of simple harmonics, combined in such a manner as to form a progressive wave, with periods dependent upon the length of the wave. The horizontal displacement of those of the first type is transverse, and they penetrate very slightly into the interior of the terrestrial mass. The others are analogous to Rayleigh's waves, and differ therefrom only through the modifications produced by gravity; consequently they have a horizontal displacement parallel to the direction of propagation. The first type travels faster than the second; hence it follows that the transverse movements must predominate in the first instants of the long waves, while the longitudinal movements will predominate later, on the contrary. Facts of this nature are fully confirmed by experiment.

* * *

While these researches, based upon the broadest and most comprehensive statement of the problem, and upon the certain foundation of rational mechanics, open the way to a profounder study of the propagation of seismic waves, the most recent and striking results of theoretic seismology are to be found elsewhere.

It is the theory of what have been called *seismic radiations* [rayons] which best affords us the hope of penetrating the less accessible sides of the phenomenon and deriving therefrom those ideas concerning the constitution of the interior of the Earth which form perhaps the most attractive object of such researches.

The ideas which underly the theory of seismic radiations are less solid and certain than those made use of in seismic mechanics. It is no longer differential equations of movement which form the point of departure, but certain principles of optical physics, which are extended, *by analogy*, to seismic waves. These are: Fermat's principle of the minimum time, the concept of the radiation considered geometrically as the orthogonal trajectory of the successive surfaces of propagation of the disturbance, the principle of Huygens of the formation of the surface of the wave as an envelop of spherical waves, and in a general manner the hypothesis of a variation of the physical properties in the interior of the Earth according to concentric spheres. These principles, and the methods of research derived from them, are chiefly applied to the waves of the preliminary tremors, and the legitimacy of such an application may be regarded as being based upon the fact that waves of short duration are concerned, which constitute, as we are in the habit of saying, isolated series [trains] of waves which rapidly disappear. For if this phenomenon were more permanent in character the applicability of these principles would be dubious. We must remember, in fact, that the principle of Huygens presupposes that the wave length is very small, while the length of seismic waves may be reckoned in tens of kilometers. Furthermore, if we desired to give to these radiations [rayons] a mechanical, instead of a purely geometrical, definition, it would be proper to apply the ideas of Poynting and of Kirchoff, and consider them as lines of the propagation of energy, and in this case the validity of the principles referred to above is far from being proven.

However, many results well worth attention have been obtained by the said method, which is probably justified only by the instantaneous character of the phenomenon; while, on the other hand, the methods of mechanical propagation which are applicable to waves of the final phase are perhaps too heavy and complicated for those of the first two phases.

Thanks to the principles of optical geometry, carried over into the seismic domain, it has been possible to obtain the equation of the curve of the seismic radia-

(*Continued on page* 407)

Emergency Seasoning of Sitka Spruce

Strength of Kiln-dried and Air-dried Spruce Compared

By L. A. Welo, Engineer, Forest Products Laboratory, Madison, Wis.

THE assignment by the War Department of a division of troops to aid in getting out Sitka Spruce needed for Allied aircraft demonstrated clearly that the suitability of a material for a particular use was more important than nearness to manufacturing centers or ease and economy of production. The War Department justified the keeping of troops at home by the fact that, of all woods which could be produced in large quantities, Sitka spruce possesses the qualities most desired in airplane woods; namely, stiffness, shock-resisting ability, and strength as a beam or post combined with lightness.

Once material with these desired qualities has been obtained with much cost and effort it becomes doubly important that the qualities be preserved during the seasoning and drying period before being shaped for final use. The recognized method of seasoning has been air drying by storing in open piles for a long period of time. It was generally though that this method of air seasoning yielded material superior in strength to kiln-dried material. It was to be expected, therefore, that manufacturers and officials concerned with airplane construction (where strength of material is so essential) would be reluctant to use any other than air-seasoned stock. However, a shortage in air-dried stock developed, as a result of the purchases by the Allied countries during the first years of the war, so that when the United States also became a belligerent and adopted a large airplane program there was no alternative but to resort to rapid artificial drying.

SPECIFICATIONS PREPARED.

In this emergency the Forest Products Laboratory of the United States Forest Service at Madison, Wis., prepared for the Signal Corps, specifications for the drying of such woods as were already in use for airplane construction and of those other species that were being considered as possible substitutes. These specifications with some slight modifications—now specification 20,500-A of the Air Service—contained two schedules: Table 1, which was generally applicable to the drying of conifers; and Table 2 for drying hardwoods.

TABLE 1.—SCHEDULE FOR DRYING SPRUCE—(SPECIF. 20,500-A).

Stage of Drying	Drying Conditions: Max. Temp.	Drying Conditions: Min. Rel. Hum.
	° F.	Per Cent.
At the beginning	120	80
After fiber saturation is passed (25 per cent.)	125	70
At 20 per cent. moisture	128	60
At 15 per cent. moisture	138	44
At 12 per cent. moisture	142	38
At 8 per cent. moisture	145	33
Final	145	33

TABLE 2.—SCHEDULE FOR DRYING HARDWOODS. (Specif. 20,500-A.)

Stage of Drying	Drying Conditions: Max. Temp	Drying Conditions: Min. Rel. Hum.
	° F.	Per Cent.
At the beginning	105	85
After fiber saturation is passed (25 per cent.)	110	73
At 20 per cent. moisture	117	62
At 15 per cent. moisture	129	46
At 12 per cent. moisture	135	42
At 8 per cent. moisture	135	40
Final	135	40

Tables 1 and 2 were based on the experience gained by the Laboratory in kiln drying investigations to prevent the great losses frequently occurring in commercial drying due to checking, casehardening, etc., and to secure better control of temperature, humidity and circulation in the kiln. The information gained through many miscellaneous strength tests was used; also that gained through tests on the effect of kiln drying on strength for 3 preliminary kiln runs that were made on partially air-dried Sitka spruce and white ash. These specifications were regarded as an emergency solution of the problem because of the limited amount of the data and the indirectness with which much of it applied to the immediate problem.

INVESTIGATIONS TO IMPROVE SPECIFICATION.

Extensive investigations were at once begun for the Army and Navy Departments. The main objects kept in view were: (1) To check the specifications; (2) to find a process or schedule that would yield better stock than either air seasoning or drying according to specifications; and (3) to decrease, if possible, the time of drying.

Taking air-dried wood as a standard, the following method of testing was used:

The test material, coming to the laboratory in log form was cut into boards or plank according to special cutting diagrams (Fig. 1) in which provision is made for test specimens in the green, the kiln-dried, and the air-dried conditions. From a few planks of each log test specimens were cut at once, and half the specimens were tested immediately, the other half being stored for air drying and future testing. The remaining planks of each log were then divided about equally among the kiln loads, the runs were made, and the planks were cut into test specimens.

This method of getting out material for tests in the green, the air-dried and the kiln-dried conditions from each log very greatly reduces the possibility that inherent differences in the material will be mistaken and confused with differences brought about by the drying. The chance for error is certainly far less than if material for test in the air-dry condition came from one tree, material for a kiln run from another tree and material for a second kiln run from still another. By obtaining the material in the foregoing manner from many trees grown in various localities it is also likely to be representative of the lumber reaching the mills and the airplane factories.

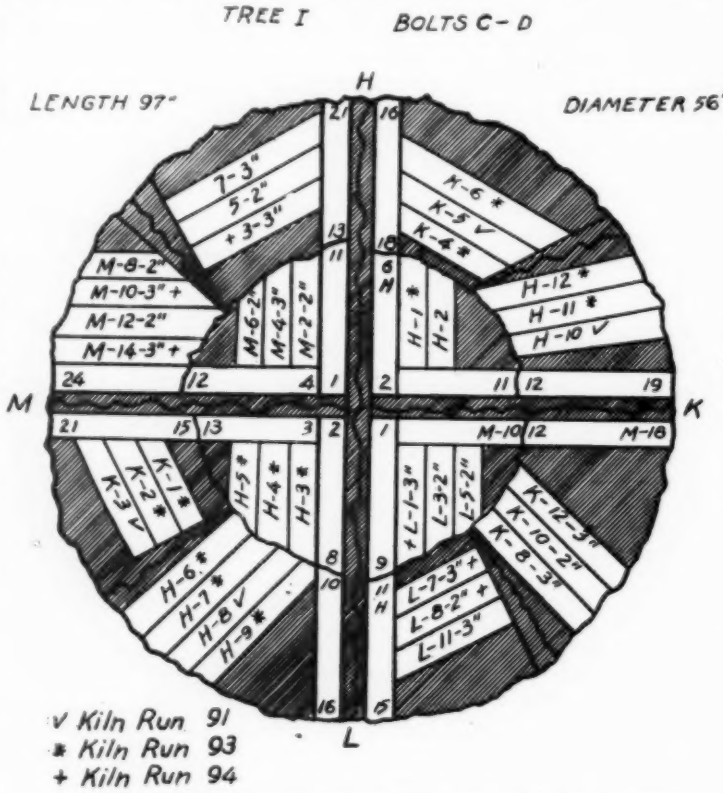


Fig. 1—Diagram for cutting Sitka Spruce logs into test specimens Material for green and air-dry tests from center flitches

Analysis of results has been based chiefly on those qualities most important in airplane woods; shock-resisting ability, ability to sustain a slowly applied load, and stiffness. In this article, the kiln conditions as to temperatures, humidities, and the effects on strength wil be described for 7 of a total of 18 runs. It is only for the 5 runs, shown in Figure 2, that the matched air-dry material has been tested. Two other runs, shown in Figure 3, are discussed because they tell us much about the effect of high-temperature drying even if there is yet no matched, air-dry material for comparison.

Since Figures 2 and 3 are practically self-explanatory, it is unnecessary to discuss the variation in the temperatures and the humidities at the various stages of drying as determined by the moisture contents of the samples. The peaks showing sudden but short rises of the humidities to 100 per cent. indicate the time when stock was steamed to relieve casehardening. The temperatures at which the steaming took place can be read from the temperature curves. All of the runs were given a steaming of from 3 to 5 hours at the beginning to attain uniform temperatures within the planks before drying conditions were established.

PILING CONDITION IMPORTANT.

Something must be said about the piling and sizes of stock, which are important factors in the drying but not such that they may be described in Figures 2 and 3. Except in runs 94 and 147, the stock was in the form of 2½ or 3-inch planks about a foot in width and piled flat. In run 93, open spaces of 6 inches were left between the planks of each tier, forming wide flues the entire height and length of the pile. The material of run 94 was of various small stock sizes averaging 2 by 4 inches and piled flat. The small sizes of the stock and type of piling were responsible for the short time of drying in run 94 (see Figure 2). In run 147, the sticks were 2½ by 2½ inches in section and about 4 feet in length and the piling was rather open. The piling in run 148 was the same as for runs 88 and 89.

Inspection of the material at the close of each run showed that, so far as it was possible to judge by external appearance, no appreciable damage existed. Casehardening was not apparent at the close of any run. In a general article of this type the results of mechanical tests made on the kiln-dried material and on the corresponding green and air-dry stock cannot be presented in detail, so that we may pass at once to a statement of the conclusions reached by the engineers after a careful study of the large amount of data.

CONCLUSIONS.

Kiln-Dried Material Equal to Air-Dried.—The outstanding fact indicated by the strength test data is the very general excellence of the material which had been kiln dried as compared with the corresponding air-dried stock. Whether we place emphasis on shock-resisting ability, on the ability to sustain a slowly applied load, or on stiffness, the kiln-dried material in general proved to be fully equal to air-dried stock from the same trees. As to the relative merits of the kiln runs for which the temperatures and humidities are shown in Figure 2, there seems to be scarcely any basis for a choice among them until the results of runs 147 and 148 are considered. Even run 91 in which the temperatures went as high as 175° F. yielded material fully as good as any of the other runs.

Shock-Resisting Qualities Involved.—Runs 147 and 148 (Fig. 3) show that, in spite of the 30° average difference in temperatures, stiffness and ability to sustain a load are retained equally well. There is, however, a significant difference in the effects of these two runs on the important quality of shock-resisting ability. In run 148 the increase in shock-resisting ability over green stock was only 85 per cent. of that in run 147. The explanation of this difference between the effects of high temperature drying in runs 91 and 148 is that the material, although of the same species, came from different trees. While material from some logs of Sitka spruce can be dried with safety at high temperatures, material from other logs may not stand such drying. One is therefore taking a chance of damaging some Sitka spruce in shock resistance by using such high temperatures as in runs 91 and 148, because, as yet there is no way known of distinguishing material which will be damaged from that which can be dried safely at high temperatures.

Proper Temperature and Humidity to Use.—What, then, are the temperatures and humidities that will be safe, and sure to yield material equal in strength to air-dried stock? It may be that a run made according to the curves of run 147 will answer the purpose, but no positive answer can be given regarding these particular conditions until the matched ma-

terial now air drying has been tested. It may be definitely stated that any run on Sitka spruce, made like Nos. 88, 89, 93, and 94 may be expected to do as well by the material as air drying, or better, and that, of these runs, No. 88 seems best adapted under ordinary conditions to give a reasonable drying time as to sizes of stock and economical piling. Apparently, runs 89, 93, and 94 dried the material in the shorter time, but it is to be kept in mind that the initial moisture content of the material was in each case lower than that of the material dried in run 88, that in run 94 the material was of small stock sizes, that in runs 93 and 94 the piling was very open and unusually favorable to rapid circulation and that in run 89 the humidity was somewhat lower during the first part of the run than is regarded as good practice when the wood is just beginning to dry.

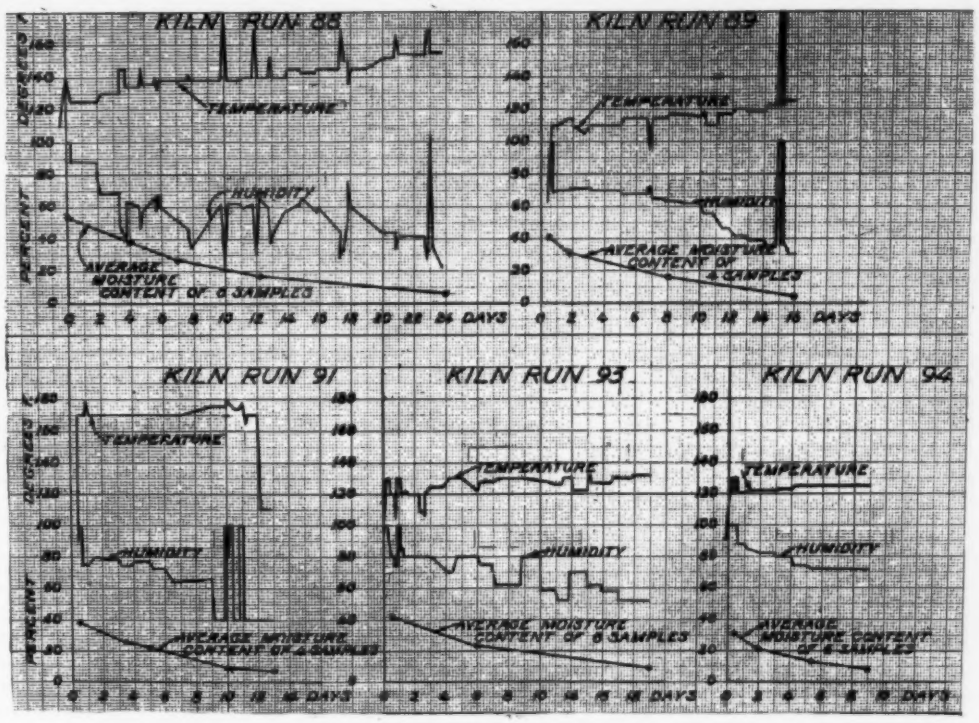


Fig. 2—Kiln conditions for 5 runs of Sitka spruce. Matched air-dry material has also been tested

Original Specification Safe.—The net result of the study of 7 experimental kiln runs here discussed is, then, that Table 1 of specification 20,500-A is a perfectly safe and satisfactory schedule for preserving the qualities that make Sitka spruce desirable as an airplane material.

Different Types of Airship*

THE stage of development now attained by air-ships, and the manner in which some of the problems of design are dealt with, were discussed before the Institution of Naval Architects by Mr. C. I. R. Campbell, who pointed out that airship design is very closely allied to the work normally performed by naval architects, and should, consequently, not be allowed to drift into the hands of those whose training has not fitted them to deal with the problems involved.

He remarked that in British practice it is the custom for design purposes to assume that the gas, the impure hydrogen used in airship envelopes and gasbags, has a life 68 lb. per 1,000 cubic feet at sea level. The practice in this matter varies in different countries, and this is the cause of much confusion when comparing the performances of foreign and British airships. The air density decreases as altitude increases, and the lift of an airship decreases accordingly. As an airship rises the external pressure falls, and the gas tends to expand. In the case of a rigid airship, where the gas is contained in internal gasbags which contribute nothing to the strength or external form of the ship, the expansion of gas can be provided for by starting from ground-level with the bags only partially inflated. Then, if it is desired to reach a height of, say, 9,000 ft., it would be economical to start with the bags only 75 per cent. full, so that on reaching the height mentioned the bags would be just full. Any further rise would then involve further expansion of the gas, causing a loss of gas through the automatic relief valves. The height at which the gasbags are just full to blowing-off pressure of the valves is called the "pressure height." As the total lift of a definite mass of gas is the same at all altitudes provided that its temperature and pressure are always those of the surrounding air, apart from the effect of humidity, it follows that the total lift of an airship is nearly the same at all altitudes provided that no gas is lost. Hence a very small vertical force is sufficient to cause a rigid airship to rise or fall between sea-level and the pressure height, and she can be navigated between these limits by means of her elevators alone without loss of ballast.

NON-RIGID TYPE.

The non-rigid type includes all those airships in which the form of the envelope is maintained solely by the internal gas pressures. The principal varieties are:

(*a*) Those having an envelope of nearly circular cross-section, the car suspensions being connected to fabric patches or long strips stuck, or sewn and stuck, on the outside of the envelope. In this variety are found the small British and American airships, using stuck patches only; the French Zodiacs, in which the suspensions are attached to long strips running longitudinally on each side of the envelope, and having reinforced edges to which the suspension ropes are attached at intervals; the German Parsevals, in which the suspensions are attached to a fabric girdle strip running round the under side of the envelope in a roughly oval curve, the envelope being reinforced by a number of braid strips which pass over the envelope from side to side and serve to conduct the lift of the envelope to the girdle and to relieve the tensions in the envelope fabric.

(*b*) The French Astra Torres or trilobe variety. In this the car suspensions pass through gas tight joints into the bottom of the envelope on the center line, and are there connected to fans of smaller ropes which lead up to attachment points on internal suspension strips at the two upper ridges or angles of the trilobe section. The three ridges of the trilobe are maintained in their correct relative position by internal fabric curtains connecting them; these curtains run continuously from end to end of the envelope, and being in a state of considerable tension tend to give a certain measure of rigidity to the form of the envelope.

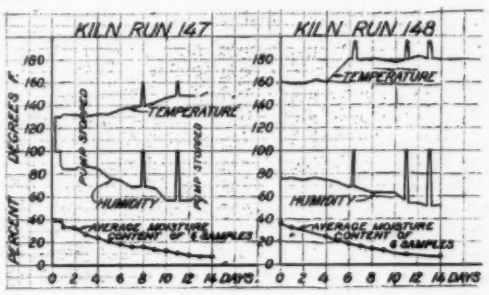


Fig. 3—Kiln conditions for 2 runs of Sitka spruce, revealing effect of high-temperature drying

For small airships up to 150,000 or perhaps 200,000 cu. ft. there is probably nothing gained by departing from the circular section envelope with stuck-patch suspension attachments. For larger sizes, up to about 400,000 or perhaps 500,000 cu. ft., the Zodiac, Parseval, and Astra types are available. For those larger than 500,000 cu. ft. the non-rigid type certainly can be, and has been, used, but its efficiency tends to compare less favorably with the semi-rigid type as size is increased.

Non-rigid airships form a class of great utility, which can be given speeds of 45 to 60 miles per hour with disposable weight percentages from 33 to 45 per cent., the lower figures applying to the smaller airships. They are particularly suitable for short distance flights and for patrol duties. Their chief merits are simplicity, ease and cheapness of production, and low cost of maintenance.

SEMI-RIGID TYPE.

In non-rigid airships the envelope absorbs a considerable part of the total weight, due to the large internal gas pressure required to give the necessary rigidity to the envelope, and also to support the bow stiffeners and tail planes against the aerodynamic forces to which they are exposed during flight. In semi-rigid airships, a longitudinal keel girder is fitted to the under side of the envelope so as to constitute a rigid, or in some types, slightly flexible backbone. The whole weight of the car or cars and the disposable weights are suspended from the keel, which in turn is supported by the envelope to which it is attached at many points along its length. The interposition of the keel therefore relieves the envelope of all local stresses, shearing forces, etc., due to the car and disposable weights. If continued to the bow and tail, the keel also gives effective support to the bow stiffeners and to the tail planes. Its general effect is, in fact, to relieve the envelope of all the loads which in non-rigid airships have to be met by the use of a relatively high internal gas pressure. As a result it is found possible to fly large semi-rigid airships of over 600,000 cu. ft. with gas pressure at the axis little more than one-half as great as those required in non-rigids of equal capacity and speed. A lighter envelope fabric can therefore be used, and sufficient weight is thus saved to compensate entirely for the extra weight of the keel girder.

A further point is that, although in a semi-rigid the maintenance of full inflation of the envelope is necessary for rapid flight, the airship can nevertheless be brought to land, and even flown slowly with the envelope. This is not feasible in a non-rigid in which tained; it becomes profitable, therefore, to divide the envelope into compartments by means of transverse fabric bulkheads, and so to reduce the risk of the airship being lost through an accidental tear in the envelope. T his is not feasible in a non-rigid in which loss of pressure means buckling of the envelope, and, in many cases, loss of the ship. The bulkheads also limit the alteration of pressure at the ends due to inclinations of the airship, and this is a further reason for the lower envelope pressure mentioned above.

In recent years semi-rigid airships have been developed by the Italians alone, who have shown great skill and ingenuity in doing so. Of the two main types one, called the Military type, has been developed by the Italian Government; the other bears the name of Signor Forlanini, of Milan. The lower limit of size is said to be about 100,000 cu. ft., but for sizes up to about 400,000 cu. ft. the advantage appears to lie with the non-rigid type on the score of cheapness, simplicity, and rapid production. The upper limit is apparently considered by the Forlanini designers to lie not lower than 1,000,000 cu. ft., and the rigid type is probably superior for greater capacities. The semi-rigid type therefore has a special value in that it fills in the gap between the largest efficient non-rigid and the smallest useful rigid airship.

RIGID TYPE.

In a rigid airship, the whole of the shearing forces and bending moments are sustained entirely by a rigid hull. The envelope, which in a non-rigid supplies the whole form and strength of the airship, has degenerated into a series of weak gasbags which have to be most carefully supported over their whole surfaces to prevent them from bursting.

In a typical rigid airship 643 ft. long and 278¾ ft. in extreme diameter, with a gasbag capacity of 1,950,000 cu. ft., the hull structure is composed mainly of triangular lattice girders made of duralumin, none of which is more than 14 in. in extreme depth of section. The hull constitutes, in effect, a skeleton tube of polygonal cross-section, with a short parallel body and long tapered ends forming the bow and stern portions. There are two main systems of girders: (1) the longi-

(*Continued on page 407*)

*From *Times, Engineering Supplement.*

Economics of Transportation in the Mississippi Valley*

Develop Southern Ports for Foreign Trade by Revising Interior Transportation

By J. R. Bibbins, Engineer

Transportation economics in the United States today has to be considered in relation not only to domestic trade but to foreign trade. Future development must take into account easy and cheap transport of goods to and from the great interior of this country to the centers of production and consumption the world over. No longer should it be proper, in the planning for trade, to be bound by the great East-West railroad lines, built up in the past by readily seen causes, but the strategic and economic position of the Mississippi Valley should be studied with a view to its logical connection to world routes. A start on such a study has been made. Its elements indicate some radical revisions in the transportation routes and methods of the United States.

A physical examination of the Mississippi drainage basin leads one to wonder why these lines of economic gravitation cannot be developed along the same lines as hydraulic flow, and then to inquire what forces and tendencies so altered this natural gravitation in the early history of the United States as to result today in the elevation, over the passes of the Appalachian range to north Atlantic tidewater, of by far the greatest proportion of the production of this valley, with all the increased expense incident to such elevation. No student can overlook for one moment the fact that the urge of commerce originated in Europe and has continued in effect throughout the century-old commercial independence of America. However, it must be patent that the study of the "vector diagram" of commerce with reference to Europe and South America, respectively, will reveal the fact that the relative value of abscissa and ordinate are changing, with the result that the force of commerce is gradually shifting toward Panama. New Orleans and Galveston have grown as southern gateways of the United States largely by virtue of the fact that other nations needed our cotton. New Orleans has profited by a triangular trade to Europe, to South America, and back to New Orleans in British bottoms. But still the great transcontinental gateways of Chicago, St. Louis, Pittsburg, etc., have witnessed the overflowing production from the vast Western plain headed for north Atlantic ports directly in contravention of the natural outlet for this territory through the southern water gates.

The answer must lie in the brains of the inhabitants of the Mississippi Valley, who represent the majority of the voting population of the United States. Their vast waterways lie idle. While dozens of freight trunks radiate from the crowded East-West tunnels of Chicago and St. Louis, not one radial trunk reaches into the Northwest from the second port of the United States. The country seemingly has been educated to think east and west, and the prevailing rate system is conceived on its east and west economic base line. What will be the result when the people of the Mississippi Valley fully conceive of a different economic base line—Chicago to the Gulf?

The Mississippi Valley Association recently convened in Chicago, showed itself to be alive to the necessities of this situation. At this convention standing committees reported upon numerous matters of fundamental importance. One of these committees, a subcommittee on the economic development of waterways, terminals and electric and highway feeders in relation to transportation, presented a report prepared by Bion J. Arnold, consulting engineer, Chicago. Colonel Arnold's report was based on instructions to investigate the now existing facilities for foreign trade; that is, the existing physical plan of the railroads, terminals and steamship lines and their capacity and adequacy for the contemplated freight movement of the valley. It also dealt with the economic policy under which these transportation facilities are used and should be used.

As a preliminary to the study, Colonel Arnold prepared a statement of principles and policies which is as follows:

1. Methods of securing actual commodity movement along natural economic lines of transit.
2. What are these natural economic lines of transit?
3. Natural and artificial barriers, preventing logical movement.
4. Necessity of curtailing man-handling of freight.
5. Economic median lines of rail transit for overseas movements.
6. Function of low-grade lines in controlling mass movement; their ultimate dependence on shipping.
7. Midcontinental gateways and their effect on commodity movement.
8. Shall the cost-of-service-plus-profit basis be allowed to control the transit movement in the valley?
9. Should overseas traffic movement be adjusted to a least-ton mileage basis—that is, shortest route, taking the relative cost of water and rail into consideration?
10. Function of storage in absorbing heavy seasonal movement and securing much desired two-way loading for steamship lines—i. e., a "balanced port."
11. Effect of policy of national waterway development upon transcontinental movement.
12. Lessons to be drawn from past waterway experience.
13. Proper economic field for railroads and waterways with respect to different classes of freight.
14. Comparative possibilities of Mississippi River and rail routes between specific points.
15. Should waterways develop as through freight carriers—i. e., largely as a full-cargo trunk line, rather than as packet lines?
16. Special terminal facilities required for: (a) Freight originating at main terminal; (b) transshipped freight.
17. Desirability of the "sailing day plan" as a terminal policy for both rail and barge lines.
18. Type of floating equipment and economic units best suited for handling different classes of cargo.
19. Can the electric railways function individually or collectively to any extent as freight carriers to and from points of rail interchange or transshipment to water lines?
20. Is there any necessity of extensive motor-highway development as a means of accelerating interior production and thus tending to guide this movement through properly designed channels or terminals?
21. Immediate steps to be taken to secure a sound development program.

*From *Engineering News-Record*, New York.

GENERAL CONSIDERATION OF PRINCIPLES.

Having put these general questions, Colonel Arnold continued with the following general consideration of the policy to be pursued and the conclusions which are to be drawn therefrom:

The Mississippi Valley should be considered as a great *drainage basin* favoring natural rather than artificial outlets. Up to the present time, the laws of economic gravitation within this drainage basin have been artificially upset to a large degree. The question now is to re-establish economic equilibrium, which involves four essential elements: (1) Rails; (2) waterways; (3) terminals, and (4) shipping.

It is contended that commerce needs *both* rail and inland water transportation, especially where a vast bulk of commodity movement runs in seasons. Railroads are expensive transportation systems when they have to be built largely for short-seasonal use. Therefore, on general principles, the capacity of the natural waterways should be drawn upon to their fullest extent where possible to relieve railroad operation of this expensive peak-load traffic.

Successful business adjusts the character of its facilities to the requirements and profits of each particular branch; that is, classfies its operation. So should the waterways be used intelligently as a co-ordinate agency to railroad transportation, rather than as a competitive agency.

But a clear definition and understanding of advantages and limitations is very desirable. To attempt to handle bulk cargo in little bottoms with no terminal facilities is manifestly wrong policy. The great waterways are trunk lines primarily, and transportation should be provided and sold *wholesale* rather than retail. Further, something more than a paved levee or even a simple wharf is required for economic handling, especially with rising wages. Frequent *man-handling* will destroy both the profits and the practical success of waterways movement. For this reason, the *"original-package"* idea is being actively worked out, by means of which transshipment from rail to barge and vice versa may take place, without breaking bulk through mechanical handling in original packages.

Over 30% of Chicago's freight passes *through* the city, carload freight being rehandled in original cars, less-than-carload freight being handled in parcels. For carload freight, man-handling has been reduced to a minimum by the terminal yards at clearing. The railroads are still wrestling with the problem of reducing the cost of man-handling less-than-carload freight.

In the Mississippi Valley's largest port, nearly 30% of the incoming freight passes over the wharves *direct* and this would probably be increased to 50% if all *freight held in transit* were included; i. e., seasonal freight held over season in storage warehouses for later transshipment. Chicago's freight has to pass on promptly, as every hour's delay means increased congestion. Overseas freight, on the other hand, must have waiting time, hence the vital importance of warehousing, storage and methods of prompt handling to clear the wharves for incoming and outgoing boats. It would be idle to build railroads without vast city terminals. It is equally idle to develop waterways without equivalent terminals; for terminals are only reservoirs in which to permit freight to "slow up" in its general movement to destination. The faster the mainline movement, the more terminal capacity is required to avoid congestion.

CONCLUSIONS AS TO POLICY.

In order that the Mississippi Valley Association may have a tangible basis upon which to organize, promote and finance the advanced policies, physical improvements and desired changes in established methods of transportation, it should undertake a transportation survey to be conducted with as little delay as possible for the purpose of argument and defense of the following program:

1. Encourage the construction of more direct trunk-line transportation from the Northwest to Gulf ports, particularly via the Alexandria-Shreveport gateway.
2. Ascertain the maximum possibilities of classification and freight handling by means of which slow and fast freight may be routed on lines best adapted thereto, with rates gaged accordingly.
3. Endeavor to secure a freer interchange between steam and electric lines than at present, in order that the latter may become more useful in the general transportation scheme than at present.
4. Consider fully the economics of motor-truck transportation in all its aspects, prior to commitments for vast expenditures in expensive motor highways, so that both motor equipment and highway expenditures may be kept within their proper economic limits.
5. Study carefully every possible means of encouraging a balanced two-way vessel movement through Gulf ports which will be perhaps the most important factor in attracting additional shipping facilities.
6. Support the Government program for inland waterway development assisted by state contributions where necessary to prevent excessive lockage time and delays on canalized routes.
7. Ascertain the reasonable *base cost of service* per ton-mile of transportation within the valley:
   - (a) By rail;
   - (b) By water;
   - (c) By rail and water;
   - (d) Cost of transshipment:
     - (1) By handling or trucking.
     - (2) By mechanical means for typical commodities and points of origin.
8. Ascertain similar base cost of service per ton-mile of both waterway and overseas haul, disregarding existing arbitraries and differentials.
9. Determine how far the cost-of-service-plus-profit basis may be allowed to control the transit movement within the valley, without too great disturbance of the existing economic structure upon which the commerce of the country is based.
10. Determine what readjustment of shipping schedules and capacity, as between various ports, is reasonably called for in order to meet this cost-of-service basis of interior transit.
11. Ascertain the desirable economic section which should be built for the Illinois waterway, the rock cuts and for locks in this and in other waterways, in order to minimize the delays in breaking up fleets of barges in transit.
12. Consider with care the economic size of barge units.
13. Consider the maximum application of the "original-package" idea for rail-river transportation, in order that a fair trial may be had.
14. Encourage the construction of barge terminals for originating or transshipped freight, and especially the provision of mechanical methods of freight handling to the maximum extent.
15. Impress upon municipalities the vital necessity

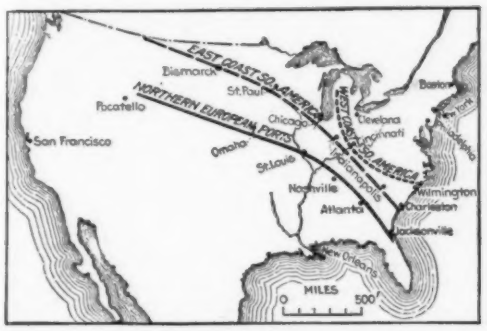
of doing their full share in providing the required terminal facilities.

Delays in transit will be the greatest enemy of inland water transportation.

ECONOMIC MEDIAN LINES EXPLAINED.

A definite conception of what is involved in the great economic questions analyzed in the foregoing statement is illustrated in the accompanying diagram, which is presented through the courtesy of the Public Belt R. R. of New Orleans, being a part of a technical study of the transportation development of that city.

This diagram shows which territory is properly tributary to the Gulf and North Atlantic ports of the United States (specifically in the diagram New Orleans and New York), disregarding all other considerations except those of rail and overseas transportation. The territory north and east of each of the lines, for



Economic median lines show zones from which overseas freight should be shipped

Goods to and from territory north and east of lines should pass through New York; zones south and west are tributary to New Orleans; based on average prevailing tariffs, assuming one mile rail haul equals four miles water haul.

instance, should ship goods to the foreign districts attached to those lines, through the north Atlantic ports. The territory south and west of each of the lines should ship and receive goods through the Gulf ports. These lines, which for the purpose are called economic median lines, are worked out on the only basis now available; that is, cost-of-service-plus-profit average rail haul in the United States and average water haul overseas with such controlling rate points as Gibraltar, Pernambuco and Panama. In other words, these lines reflect what the rail and water carriers actually charged to the shippers for transportation.

Considering Panama as the water-gate to the Pacific and the west coast of South America, it will be seen that almost the entire Mississippi Valley is logically tributary to Gulf ports. For the east coast of South America and South Africa, the Chicago gateway marks in general the dividing line between Gulf and Atlantic ports. If we consider northern European ports, it appears that almost half of the Mississippi Valley should in fact be tributary to the Gulf ports.

Is this allocation carried out in practice, even under present rates? The answer will be found partly in the great preponderance of east-west transportation lines, incidentally in the comparative absence of the trunk lines from the mouth of the Mississippi into the great Northwest.

It may be contended that these lines are not properly conceived, as they must be drawn for specific cases. Theoretically, this is quite true, and yet the diagram illustrates forcefully the general situation. It is fundamentally based upon the assumption of one-mile rail-haul equals four miles of water-haul. Considering the fact that transcontinental rates are constructed upon a New York-Chicago base line with its extensive detours or mountain climbs, it is plain that if such a diagram were reconstructed on the basis of a water-grade base line of Chicago to the Gulf, all three median lines would move eastwardly, and the result would be still more conclusively in favor of the development of Mississippi Valley through the Gulf ports.

In view of these conditions, should not the United States of America, with the largest systems of transportation on the face of the globe, awaken to the necessity of a deeper consideration of this vital subject of internal transportation and lift this question out of the domain of legal and political controversy, and place it squarely upon the basis of scientific analysis and uncontrovertible fact—so that unco-ordinated state legislation and ill considered action by both labor and Congress may not culminate in retarding rather than developing this great agency of transportation, which has been chiefly instrumental in the development of our commerce as it is today?

Different Types of Airships

(*Continued from page 406*)

tudinals, of which there are 25, nearly equally spaced round the circumference and running from end to end, following the surface of the hull along the angles of the polygon; (2) ring girders called transverse frames running completely round the circumference at about five-meter intervals. Every alternate one of these ring girders is "a main transverse frame"—i. e., it is made specially strong, and fitted with a system of wires arranged on much the same principle as the spokes of a bicycle wheel, so as to maintain rigidly its polygonal shape. The main transverse frames are the equivalent of the bulkheads in a ship, holding the hull to its correct transverse form. The structure is completed by cross bracing wires in all the panels on the surface of the hull between the longitudinal and transverse frames. A structure is thus obtained which behaves as a slightly elastic tube capable of resisting bending moments and shearing forces in a manner similar to that of the hull of an ordinary ship. Running along the inside of the bottom of the hull is a passage way, at each side of which are stowed the petrol tanks, water ballast, bombs, &c. The structure of this passage way is so arranged as to constitute a very stiff keel girder running nearly from the bow to the stern. As the hull bending moments usually produce compression in the lower part of the hull, the stiffening so afforded to the hull at this part is of great value.

The gasbags fill as completely as possible the interior of the hull. Each occupies the space between two main transverse frames—*i. e.*, a fore and aft length of 10 meters, but a clear ring space about 12 in. in average depth is left between the outside of the gasbag and the outer cover. Each is fitted with an automatic spring-loaded escape valve, and most of the gasbags have also hand-controlled valves at the top for reducing the buoyancy when required—*e. g.*, when landing. The gasbags are made of single-ply cotton fabric lined with gold-beaters' skin. The finished weight per square meter is not more than 160 grams. The total weight of the gasbags is about four tons.

ADVANTAGES OF INCREASED SIZE.

The most striking improvement in the commercial value of airships is to be obtaind by increased size. To enable an airship of 2,500,000 cu. ft. capacity, having a maximum speed of 70 miles an hour and a disposable lift 50 per cent. of the total—*i. e.* about 38 tons—to cross the Atlantic at 55 miles an hour she should carry fuel and oil for, say, 4,500 miles, so as to have a margin in case of meeting contrary winds. Of her disposable weight three tons can then be allotted to crew (30) and effects, 8 tons to water ballast, 18 tons to petrol and oil, ½ ton to stores and spares, and 8½ tons to carrying capacity for passengers, luggage, food, &c. The weights may be divided roughly into three groups: (1) Those which may be considered to be a constant proportion of total lift (hull, fabric, and control, navigating crew and stores, and water ballast), 40 tons, or 52½ per cent. of the total lift; (2) those varying as the power (machinery, fuel, engineers, and power cars), 27¾ tons, or 36½ per cent.; and (3) passengers, 8¼ tons or 11 per cent. As far as can be seen, the items in group (1) may be taken as a fairly constant proportion—*i. e.*, 52½ per cent. of the total lift over a large range of capacity. But in an airship of double capacity, *i. e.*, five million cu. ft., designed for the same length of voyage and the same speed, the total lift will be made up of hull, &c., 82 tons (52½ per cent.), and machinery, &c., 44 tons (29 per cent.), leaving 28 tons (18½ per cent.) for passengers.

Thus by doubling the capacity, the carrying capacity for passengers, &c., is increased 3.4 times, and raised from 11 to 18 per cent. of the total lift. As the running costs of the larger ships will be less than double those of the smaller—*e. g.*, the cost of petrol per voyage will be only 1.6 times as great—it is clear that the larger ship is far better commercially than the smaller one. In fact, the costs per voyage per ton carrying capacity in the five million cu. ft. airship would certainly be less than one-half of those of the 2½ million cu. ft. airship. Those who contemplate starting airship services should realize the probable trend of development, and make provision accordingly in arranging their sheds and plant. A shed can at any time be lengthened without excessive cost, provided that care is taken to adopt a light form of door which does not require extensive foundations. Alterations to the height and width are, however, usually impracticable, and these dimensions should, at the start be dealt with generously.

The Mechanics of Earthquakes

(*Continued from page 403*)

tions in the interior of the Earth, and to derive therefrom a ratio which expresses the time of propagation from the epicenter to a definite point upon the surface of the Earth. This function of the distance of the epicenter, represented graphically, gives what is called the *curve of the time*. This can also be constructed, with an approximate degree of correctness, by means of coefficients deduced from experiments, and this leads to the construction of tables from which may be determined the distance of the epicenter from any observation station whatever.

According to the theory indicated the various radiations which start from the epicenter (supposing the origin of the earthquake to be not very deep), must necessarily penetrate the deeper terrestrial strata to a distance which is proportional to that of the distance at which they reappear upon the surface of the ground. The knowledge of this curve of the time enables us to determine the maximum depth to which the radiations will be able to penetrate. It varies in general with the continuity, but when the depth is about 1,300 km. the curve which represents it undergoes an abrupt change of direction, first as respects the transverse waves, and then the longitudinal waves. In the same way we find that down to a depth of a little over 1,500 km. the speed of the longitudinal and transverse waves increases in proportion to the depth, but becomes constant at this point.

It is these results which afford us the greatest surprise, and which gratify our desire to penetrate the depths of our planet by means of our researches. The simultaneous appearance at a certain depth of features peculiar to the magnitudes upon which the seismic phenomenon depends furnishes solid corroboration of the hypothesis that at such depths anomalies in the physical structure of our globe actually occur. Thus the theory that the latter is composed of a nucleus which is chiefly of metal and which is covered by a rocky crust of a thickness varying from 1,300 to 1,500 km. is brilliantly confirmed. It is fortified likewise by the calculation of the coefficient of Pisces by means of the values of profound rates of propagation; we find almost constant values for this coefficient down to the depths indicated and these values are very nearly equal to the average values met with on the surface.

Other hypotheses have been formulated by Wiechert and Zöppritz to obtain the curve of the time. They may be reduced, in substance, to a law which expresses the speed of propagation of the seismic radiation as a quadratic function of the distance from the center of the Earth. It results from this that the seismic radiations can be represented by circles. The determination of the curve of the time, and consequently that of the depth of penetration of the radiations and of the speed at various depths can in this case be obtained by means of an integral equation which is the first to appear in mathematical analysis, and whose solution we owe to one of the greatest geniuses of analysis ever known to the world of science, Niels Abel. Thus after the lapse of a century Abel's equation reappears in its simple and elegant original form to assist in the solution of a seismic problem. The results obtained by the methods of Wiechert and Zöppritz, which are more precise from the numerical point of view, agree qualitatively with those to which we have already referred.

* * *

At the Congress of Mathematicians held at Cambridge in 1912, Prince Boris B. Galitzin, the illustrious seismologist whose premature death occurred two years ago, in setting forth the foundation upon which rests the seismology of theory and of observation, laid stress on the necessity of the intervention of mathematicians in the said science, saying, "You will have seen during this last hour how many seismological problems require further mathematical treatment, and it is useless to mention how welcome and important the friendly help of the pure mathematician would be to the seismologist standing bewildered in front of the wierd and intricate problems of modern geophysics."

We too would fain close this brief and perhaps incomplete review of modern seismological theories by the same well justified appeal—and this not only for the sake of the progress in the knowledge of our Earth which is so much to be desired, but also for the sake of the mathematical sciences themselves, which always receive new and fecund impulses from every contact with physical reality, while if left to themselves they all too readily grow sterile in a closed cycle of never renewed ideas.

Electric Propulsion for the U. S. S. New Mexico—III*

The Main Control Equipment, Centralized and Flexible

By C. T. Hentschel

[Continued from Scientific American Supplement for June 21, No. 2268, Page 397]

The development of a new idea, such as the electric propulsion of vessels, naturally brings with it the necessity for designing suitable auxiliary apparatus; and this is in the fullest sense true of the electrical propulsion control equipment for the U.S.S. *New Mexico*.

At the beginning it was realized that, if speed of action and intelligent interpretation of commands were to be attained, the control of the main switching, the generator field adjustment, and the steam adjustment must be centralized at one point. This brought about the design of the propulsion control cell[1] which contains all the means of control and switching (with the exception of the generator disconnecting switches) for the two turbine-generators and the four propulsion motors. (Fig. 1.)

The list of devices includes:

Two generator disconnecting switches for isolating the generators and providing a means for changing the generator connections.

One bus-tie switch for connecting the opposite pairs of motors to either generator or for separating them when it is desired to use two generators.

Two reversing switches for changing the direction of rotation of the motors for the purpose of reversing the direction of travel of the ship.

Two pole-changing switches for changing the pole connections in the motors for different conditions of operation.

Two operating levers and mechanisms for reversing

Two operating levers for pole changing.

Four motor disconnecting switches for isolating the motors.

Two bulkhead panels (bulkhead piercing).

Two field-control levers.

Two field switches.

Two booster-field rheostats.

Two speed-control levers.

Two steam-limit levers.

Two steam-limit indicating switches.

A complete set of interlocks, both electrical and mechanical, to safeguard the operator and also to produce certain sequences of operation of the different devices necessary for the proper control of the ship.

Figure 2 shows a diagram of the arrangement of cables and switches in their relative order.

THE CONTROL CELL.

The control cell, shown partially assembled in Fig. 3, is rectangular in shape 16 ft. 8 in. wide, 9 ft. deep, and 11½ ft. high. It is built of 4-in. channels, strongly riveted and bolted together to form a solid unit in order to withstand the vibrations due to machinery and propellers and also the shocks resulting from gunfire.

The cell is firmly anchored to the floor of the control room and machinery deck and it has no further supports. It is located in the center line of the ship and has ample passages around it. The outside surfaces are covered with steel basket-weave grille, except in the places occupied by the instrument, gauge, and control panels.

The cell is divided by a fore-and-aft aisle, shown in Fig. 4, into port and starboard sections, each section controlling a generator and two motors; and it is further divided by a thwartship aisle, Fig. 4, forming a natural division between the reversing and the pole-changing switches. This arrangement permits of ready access to all the devices. Grille doors are installed on the port and the starboard sides. The doors are provided with magnetic locks energized from the field circuits, so that the cell cannot be entered unless the field breakers are open. This protects the operators against contact with the high-tension circuits.

The cell is open at the top but a steel roof is installed about two feet above and extends about 12 inches on all sides. Without interfering with the ventilation, this roof protects the cell against the possibility of water dripping from above and the accidental dropping of tools into it. Inside the cell, and allowing sufficient headroom for operation, are mounted the four main bus bars which consist of two laminations of 5 by ¼-in. copper and which are located in the forward half of the cell. The other half of the cell contains the motor buses in the same plane. These consist of two laminations of 2 by ¼-in. bars.

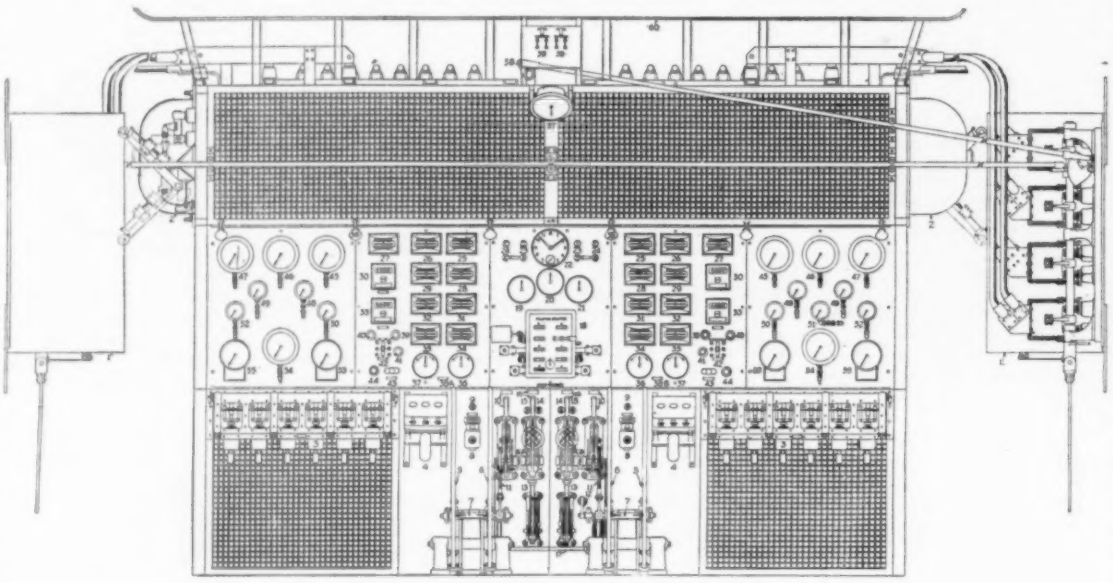


Fig. 1—Main control switchboard and cell

INSULATION.

The problem of insulation was a serious one. On account of the vibration due to running machinery and to the more serious matter of gun shock, the service on a battleship is very severe. It was obvious that porcelain could not be used, and therefore it was decided to utilize a molded compound insulation. Two types of insulators were produced; one for use in insulating the studs of the switches, and the other for supporting the buses and connections. [These are not figured here.]

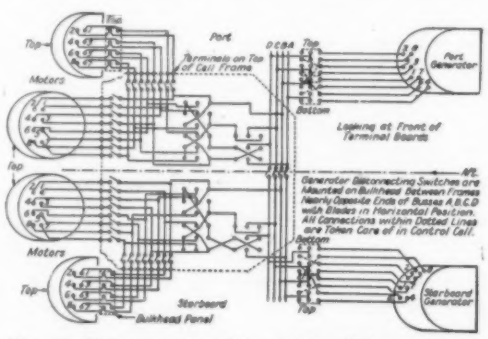

Port
Terminals on Top of Cell Frame
Top
Motors
Bottom
Looking at Front of Terminal Boards
Port Generator
Generator Disconnecting Switches are Mounted on Bulkhead Between Frames Nearly Opposite Ends of Buses A.B.C.D with Blades in Horizontal Position. All Connections within Dotted Lines are Taken Care of in Control Cell.
Starboard
Bulkhead Panel
Starboard Generator

Fig. 2—Diagram of wiring and switches between turbin-generators and propulsion motors of the New Mexico

GENERATOR DISCONNECTING SWITCHES.

The generator disconnecting switches, Fig. 5, are eight-pole, double-throw and are rated 5,000 volts, 1,200 amperes. In addition to their serving the purpose of isolating the generator, they are used for changing the connections in the greater windings.

The switch blades are L-shaped which permits a complete throw-over with only 90 deg. of actual movement. There are two laminations per pole. The poles are connected in pairs by a cross-head which, by means of couplings and a wooden rod, is connected to a crank keyed to the operating shaft of the switch. The hinge blocks are connected in pairs by copper bars arranged for cable connections to the main busbars at the top of the cell. The studs extend through insulators securely locked to a cast-metal base, which is bolted to the fore-and-aft bulkheads forming the boundaries of the control room. In this manner, the switch in addition to its regular functions serves as a cable entrance panel through the watertight bulkhead between the turbine and the control compartments.

The switches are mounted on end with the shafts vertical and are operated by means of a stout hand lever which is hinged at its fulcrum so that it can be let down into a vertical position when not in use, thus preventing its obstructing the passageway on either side of the control cell.

The shaft is provided with a notched quadrant and a roller pawl actuated by a heavy spring. This gives the operator an indication when he has reached the open or closed position of the switch.

BUS-TIE SWITCH.

The bus-tie switch, Fig. 6, is four-pole, single-throw and is rated 5,000 volts, 2,400 amperes. It is used to tie the port and starboard generator buses together when only one machine is used to drive all the motors. The blades of the switch consist of two laminations per pole, which operate between contact clips set into suitable blocks attached directly to the bus bars. They are in turn connected by means of couplings and wooden insulating rods to bell-cranks keyed to the operating shaft.

A hand lever, directly attached to the shaft and operating in the thwartship aisle, provides a means for throwing the switch, but, owing to the magnetic locks on the cell doors, it is not accessible until the field circuit has been opened.

REVERSING AND POLE-CHANGING SWITCHES.

The operation of reversing and pole changing is accomplished by the use of double-throw, oil circuit breakers, Fig. 9, made up in single-pole units each having a capacity of 1,500 amperes at 5,000 volts. The reversing switch is triple-pole, each pole consisting of two units connected in multiple. They are mounted directly behind the front wall of the cell and are separated by the fore-and-aft aisle as shown in Fig. 3. Inter-connections between the switches, and from the switches to the main busbars directly above, are made with heavy copper bars. The studs are insulated from the frame by means of bakelite compound insulators.

The contacts are of the brush type and are provided with secondary arcing tips on the brush, and burning plates on the fixed blocks. All these parts are easily renewable. The contact arms are hinged to the center stud and the carrying capacity is maintained by flexible copper connectors fastened between the center stud and the brush.

Each brush lever is connected by means of an impregnated wood rod and a coupling to the switch mechanism which is mounted on the cover frame and the mechanisms are connected six in tandem across the tops of the switches. These six mechanisms are operated in unison by means of a toggle arrangement

*Reprinted from *General Electric Review*.

[1]"Controlling the Propulsion of the *New Mexico*," by H. F. Harvey, *Gen. Elec. Review*, April, 1919, v. 23, p. 278.

which is connected to the bell-crank that communicates with the operating mechanism as shown in Fig. 7.

Each breaker unit has its individual oil tank for the handling of which an adjustable platform has been installed.

The pole-changing switches are identical with the reversing switches, but they are used in single capacity and are connected to the motor buses mounted above them and also to the reversing switches.

OPERATING MECHANISM.

The switches are operated from the front of the board by means of the large levers shown in Fig. 7. The two inner levers are for reversing and the two outer ones for pole changing. They are pivoted on the pedestals and communicate with the oil circuit breakers through a pipe and crank mechanism to the operating shafts located under the breakers and thence through the vertical pipe to the switch mechanisms. The levers have three positions, the vertical one being "off."

MOTOR DISCONNECTING SWITCH.

The four motor disconnecting switches, Fig. 8, are eight-pole, single-throw and are rated 5,000 volts, 600 amperes. They are mounted at the top of the control cell, one on each side for the port and starboard outboard motors, and two at the back for the inboard motors which are located directly back of the cell. The switches are of single-blade construction, each blade being connected by means of couplings, insulating rods, and cranks to a common shaft for simultaneous operation. They are back connected through bakelite insulators and are operated by a handle on the outside which can be reached from the deck by a switch hook.

The lower studs are connected to the motor buses while the upper studs are led out at the top of the cell over insulators by means of connection bars and terminals to the motor cables.

A latching arrangement on the hand lever prevents opening the switch under vibration. This latch is automatically relieved by the normal use of the switch hook. The switch is provided with a sheet-iron cover so that accidental contact with live parts is imposible.

BULKHEAD PANELS.

Two bulkhead panels are provided to carry the motor leads through the port and starboard bulkheads. These consist of a cast composition base mounting eight bakelite insulators, having a copper stud in each firmly locked by means of clamping nuts at each end. Terminals on each end provide means for attaching the motor cables and the connections to the motor disconnecting switches.

FIELD CONTROL.

The control of the generator is accomplished by the use of a booster set which is used either to buck or to boost the main field.

The booster set is regulated by means of the booster-field rheostat, which is controlled by the field-control lever, shown in Fig. 10.

Pulling the lever out from the board 30 degrees closes the circuit of the solenoid operating the field switch (which is mounted on the exciter board) and places the rheostat switch in the maximum-buck position. Continuing the movement of the lever another 30 degrees, which covers 28 steps of resistance, progressively relieves the "buck" and allows normal excitation to be impressed on the main generator. The following and last 30 degrees of motion produces a gradual boosting of the field over a range of 28 more steps of resistance to the maximum point. This excess

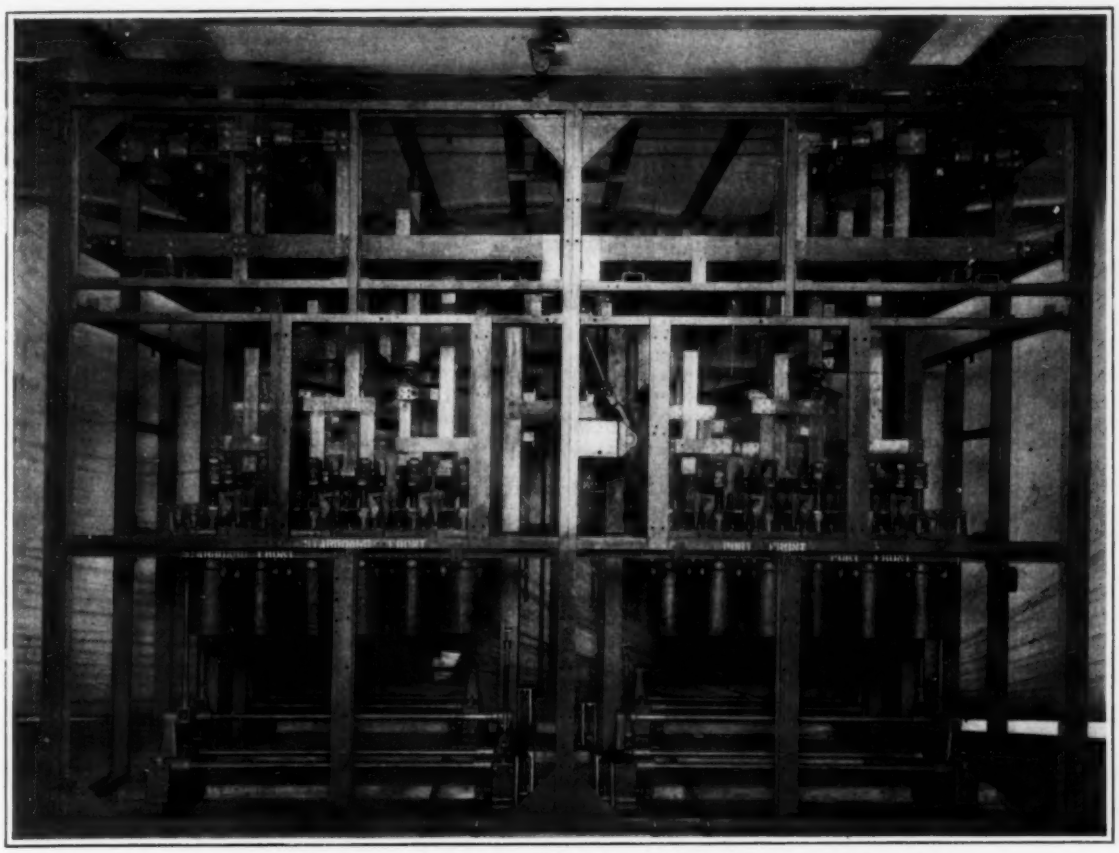


Fig. 3—View (front) of control cell partially assembled, showing fore-and-aft aisle

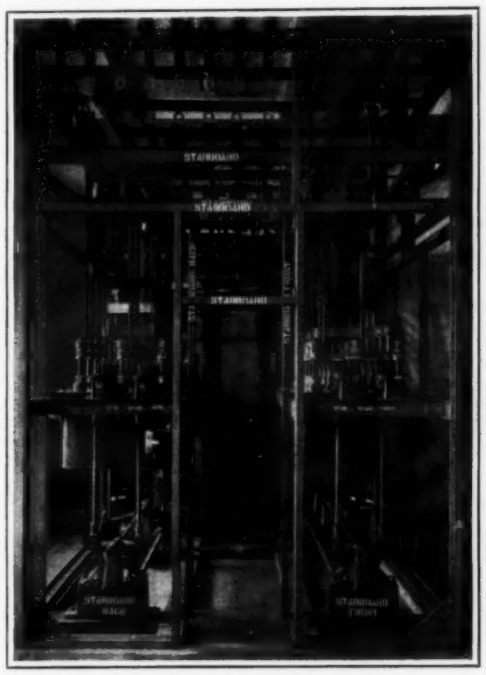


Fig. 4—Starboard side of control cell, showing transverse aisle

field current is necessary for pulling the motors into step, but it must not be maintained longer than necessary. To insure this condition, the lever is provided with a spring-return action augmented by a stout spring and lever arrangement in the pipe mechanism, near the rheostat, which returns the lever mechanism and rheostat switch automatically to the normal excitation position when the handle is released.

The hand lever is made of polished steel and straddles a notched quadrant. It is provided with a latching lever operating in the notches, thus giving a ready means for fixing the lever at any desired position. The notches in the quadrant cover only the range between maximum buck and normal field, so that the lever cannot be locked in the over-excitation position. The booster field rheostat is mounted in the cell structure on either side of the fore-and-aft aisle near the rear wall.

The field switch is a double-pole, solenoid-operated circuit breaker rated 400 amperes 250 volts. It is equipped with magnetic blowout coils at the secondary arcing tips and with a trip coil for connection to the contacts of the balance relay, Fig. 9.

SPEED CONTROL.

Speed control is accomplished by adjusting the amount of steam flowing to the turbine, and it consists of two control levers for each turbine, one for speed control and the other for the purpose of limiting the number of open turbine valves.

The speed-control or steam lever, Fig. 10, is mounted at the side of the field-control lever and is similar in design. Its throw is limited to 45 degrees and it has notches corresponding approximately to ¼, ½, ¾, and full speed. In addition to those, to provide a means for obtaining any intermediate adjustments by small increments, a hand wheel and screw arrangement is installed as shown. A four-spoked locking wheel is provided on the screw for holding the adjustment when made.

At the back of the board the lever ends in a crank and coupling which are attached to a shaft and a crank mechanism by means of which the motion of the speed lever is communicated to the operating levers at the turbine.

STEAM LIMITING LEVERS.

The steam-limit lever, Fig. 10, is mounted below the speed lever and is similar in design, except that it is smaller. It has a throw of 90 degrees and is equipped with a spring arrangement at the hinge by which the lever is thrown into full-valve position when the speed lever is thrown into the off-steam position. This is accomplished by means of a connecting rod between the two which actuates the tripping mechanism at the proper time. The quadrant has 20 notches into which the heel of the latching lever fits when released. This gives 20 coarse steam adjustments which can be made independently of the speed lever and without interfering with the action of it.

This lever is connected by a shaft mechanism, similar to the one employed for the speed lever, to the valve control arm at the turbine.

STEAM-LIMIT INDICATING SWITCH.

Installed at the end of the steam limiting mechanism and on the valve-limit hook is the steam-limit indicating switch. It consists of a light switch arm installed in the hook and operated by the valve limiting arm in the hydraulic control mechanism. Here a roller operates upon the collapsible plate and link arrangement which is connected to the switch arm, causing the arm to move its contact over a set of contact buttons suitably insulated. The contact buttons are connected to the 125-volt, direct-current circuit and to a set of indicating lamps on the control board.

INTERLOCKS.

When a large number of devices, such as those described, are gathered together, it is readily discernible

that means must be provided to prevent the making of mistakes and to confine operations to their proper sequence, therefore the very elaborate set of mechanical interlocks, described in the following, were designed and applied to the various devices:

The Generator Disconnecting Switches

(1) Must not be opened or closed when energized.

This operation is prevented by the magnetic lock, Fig. 5, which interferes with the rotation of the shaft and which is actuated by the field circuit when the field switch is closed. This means that the field-control lever must be placed in the vertical (field-off) position before a disconnecting switch can be moved.

(2) Must not be closed when the bus-tie switch and opposite generator disconnecting switch are both closed.

(3) Must not be closed in the high-voltage connection when the bus-tie switch is closed, Fig. 6.

(4) Must not be closed in the low-voltage position when the bus-tie switch is open, Fig. 6.

The Bus-tie Switch

(5) Must not be closed when both generator disconnecting switches are closed, Fig. 6.

(6) Must not be opened or closed when energized.

This protection is secured by the magnetic lock on the cell doors which prevents them from being opened unless the field circuit is "off."

The Reversing and Pole-changing Switches

(7) Are electrically locked by the locking magnet, Fig. 7, so that they cannot be opened until the line current has dropped to a predetermined value as governed by the undercurrent relay.

The coils of this relay are connected to the secondary circuits of the line-current transformer and its contacts operate the magnetic lock through the 125-volt excitation circuit.

The Reversing Switches

(8) Are interlocked with the pole-changing switches by means of the interlock box shown in Fig. 7, so that the former may not be thrown in the astern position unless the pole-changing switches are in the 36-pole connection and, conversely, the pole-changing switches cannot be thrown in the 24-pole connection when the reversing switches are in the astern position.

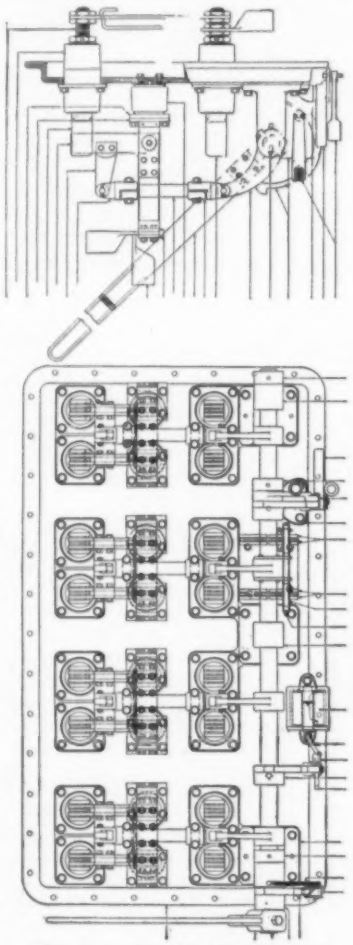


Fig. 5—Generator disconnecting switch

The Reversing and Pole-Changing Switches

(9) Are also locked by the field-control lever, so that they cannot be operated unless the field lever is in the vertical (field-off) position.

(10) Are further interlocked cross-ship with the field lever on the opposite side, so that they cannot be operated when the field switch is closed.

This interlock is shown in the lower part of Fig. 10 and consists of a shaft rotated by means of the pipe and bell-crank arrangement connected to the bus-tie switch operating a shaft as shown in Fig. 6.

The rotation of this shaft causes an extension of a set of springs attached to a second and a third shaft which are connected by links to the locking cams of the reversing and pole-changing switches on both sides.

The shafts, however, lock and cannot rotate until one of the field levers has been pulled out. The locking of the port switches is subject to the starboard field lever and vice versa; and the whole interlock is made inactive by the opening of the bus-tie switch.

The Motor Disconnecting Switches

(11) Must not be operated when alive, and to prevent this they are equipped with a locking magnet, Fig. 8, connected to the field circuit.

Field-control and Steam-control Levers

(12) The field-control levers are interlocked with their respective reversing and pole-changing switches, so that these switches cannot be operated when the field lever is in the field-on position.

(13) The field-control levers are also interlocked with their respective speed-control lever, so that the field may not be taken off the generator without first pushing the speed-control lever to a low-steam position.

(14) The speed-control lever is interlocked with the field lever, so that only a limited amount of steam may be admitted to the turbine before the field circuit is closed.

(15) The speed-control lever is interlocked with the steam-limit lever, so that whenever the speed lever is moved to the off position the steam-limit lever is tripped to the full-valve position.

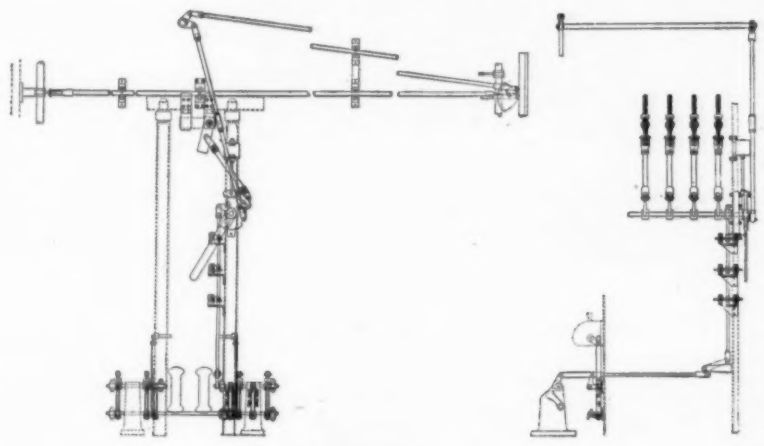


Fig. 6—Bus-tie switch

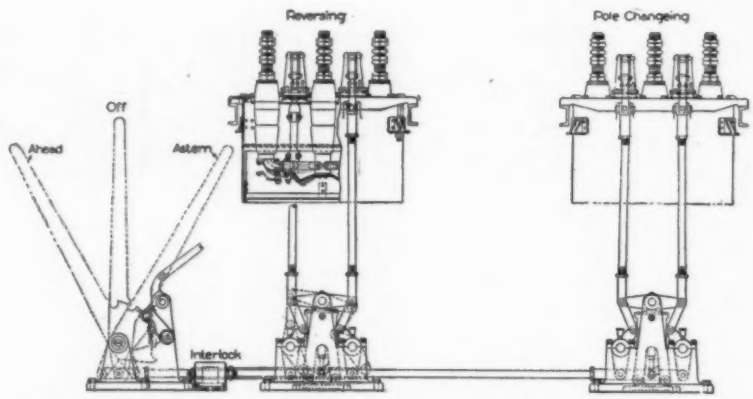


Fig. 7—Reversing and pole-changing oil circuit breakers with operating mechanism

The Color of Water*

By Wilder D. Bancroft

"There is still another point which calls for attention. If the yellow color of a liquid is due to the suspension of a certain number of solid or liquid particles, the color should disappear as the particles sink; it should be ephemeral. If this were true, the suggested explanation of the different colors of natural waters would present a real difficulty; but this is not the case. I have allowed a turbid lime-water solution to stand for seventeen days in the observation tubes. At first no light came through, but after some time the lime began to precipitate in the tube and the liquid became more and more green. At the end of twelve days the water was so clear that one could see through the tube a light pencil mark on a piece of paper. The color of the water was green, nevertheless, and remained so. It was evident that I was dealing with a solution of lime in water without any real suspension of solid matter, and yet there was enough yellow left to form a green with the blue of the water. Turbid waters containing bicarbonate of calcium or of barium in suspension show the same phenomenon, whence it follows that the resistance to the passage of light manifests itself also when light pases through saturated solutions where a precipitate is ready to form. This last might be called a nascent precipitate by analogy with the nascent clouds which Tyndall has taught us to recognize. To test this point experimentally, I have made at 18° a nearly saturated solution of pure calcium chloride containing no iron. In the observation tube this solution was a beautiful greenish-yellow. When diluted with water or when the thickness of the layer was decreased, the green became more marked. An almost saturated solution of pure magnesium chloride has shown a very pure golden yellow. A saturated solution of equally pure sodium chloride was wonderfully transparent and had a magnificent chrome-green color. I have not examined solutions of other salts because of the difficulty of getting them really free from iron. I believe nevertheless that it is proved that the yellow color produced by dissolving a salt depends less on the amount of salt dissolved than on the nearness of the solution to the crystallization point. Small amounts of a slightly soluble salt will produce the same effect as large amounts of a more soluble substance. To test this directly, I boiled pure, blue, distilled water for some time in a glass flask. It is known that glass is slightly soluble in water. When the cooled water was poured into the observation tube, it proved to be completely opaque. After some hours a deep yellow light passed and at the end of two days it became green and remained so. Its clearness was then very great, but the small amount of transparent material which had been taken from the glass was enough to color it green.

"We can now show how the observed facts may be used to account for the colors of natural waters. We start with the assumption that a sufficiently thick layer of absolutely pure water has a beautiful blue color. If small amounts of colorless salts are in true solution, the color of the water will remain blue; but if the water contains greater or lesser amounts of a nascent precipitate the light passing through the water will be a more or less deep yellow. There may even come a point at which no light will pass and the liquid will appear opaque; in other words, black. The yellow light will necessarily blend with the blue of the water to form a series of tints which will vary with the amount of yellow from greenish-blue through bluish-green to green. If there is too much yellow, the blue will disappear and the water will be a brown-yellow or even darker.

"Let us see now how these conditions may be realized in nature. The sparingly soluble substances in the natural waters, which may appear as nascent precipitates, are for the most part calcium carbonate, magnesium carbonate, silica, aluminum silicate or alumina. It is not necessary to consider the more soluble substances such as the chlorides and sulphates of sodium and magnesium because they do not occur in sufficient quantities to produce the effects in question. A blue water like the Lake of Geneva, or, better, like the Lake of Achen in the Tyrol, must have the calcareous matter more completely dissolved the more blue the water is. There must therefore be a sufficient amount of carbon dioxide to form calcium carbonate. A green water, on the other hand, like that of the Lake of Constance, must have the calcareous matter in a less perfect state of solution, which must be due to there being relatively less carbon dioxide in the water. It is interesting to note that these predictions are

*Continued from Scientific American Supplement, No. 2268, page 395.

verified. In 1848 Sainte-Claire Deville analyzed the green water of the Rhine at Strassburg and the blue waters of the Rhône at Geneva, determining also the dissolved carbon dioxide.[19] The data which interest us are given in Table IV. When referred to a constant quantity of calcium carbonate there is relatively nearly twice as much carbonic dioxide in the waters of the Rhône as in those of the Rhine. The calcareous matter is therefore dissolved more completely in the former case and, as a matter of fact, the waters of the Rhône are blue.

"If it is true that, when other things are equal, a calcareous water is more blue the more completely the calcareous matter is dissolved, it ought to be possible to make a blue water green by bringing it in contact with lime-stone. The free carbon dioxide would then be converted completely into calcium bicarbonate. In the Lake of Achen the water is a deep blue out in the lake and a most beautiful chrome-green along the northern shore where the water is shallow and the bottom consists of lime-stone pebbles from which the waves grind off invisible particles of calcium carbonate, thus causing a change of color. The greenish tones of shoals at sea and along the edges of lakes are probably due to the same thing. The sands of the sea contain fragments of crushed shells and the lands along the shores of the lakes are usually sufficiently calcareous to saturate part of the carbon dioxide in the water.

TABLE IV.
(*p. p. m.*).

	Rhine.	Rhone.
Calcium carbonate	135.6	78.9
Free carbon dioxide	7.6	7.95

"So far we have considered only the calcareous matter; but silica and alumina can produce the same effect. A green water might contain no trace of calcareous matter, in which case the silica or alumina would have to produce the color. Would a water containing alumina and silica give different tints and would it be possible to remove the alumina in any simple and natural way? The answer to this is easy. We know that clay or aluminum silicate forms a pseudo-solution in water though not soluble in the true sense of the word. The water of a river flowing over a fat, clayey mud, does not become completely clear on standing. Although the clay is not dissolved, it acts as though emulsified in the liquid. If one adds to the water a solution of a salt, such as sodium chloride, the aluminum silicate precipitates rapidly. This may be observed on an enormous scale at the mouths of large rivers. Their waters remain turbid even though the current has almost disappeared, so long as they do not mix with the sea-water. When this happens, the mud settles rapidly and this accounts for the formation of those deltas which are built up grain by grain and yet finally dam the river which formed them and force it to change its course. When the alumina precipitates the water becomes blue again. Reference has been made to the observations of Schleinitz on board the *Gazelle* as to the sudden changes in the color of the sea. He noticed that there was an increase in the density of the water when the blue color reappeared and he therefore concluded that the blue color was due to the salt. The real explanation is that the salt precipitates the aluminum silicate, which had caused the green color, when present in suspension in the water.

"One other point may be raised. Is it not possible that the polarization of the light observed by Hagenbach and by Soret in the Swiss lakes was due to the reflections which produce the yellow color rather than to reflections producing the blue color?"

[19] It is surprising that these two analyses are the only ones given in the chemical literature. Are there no others?

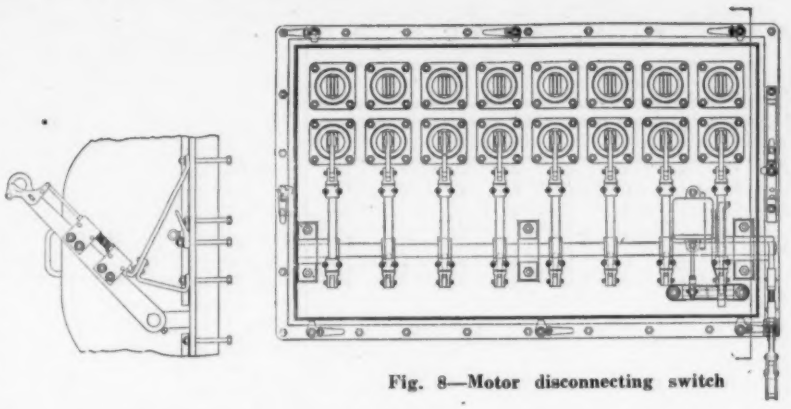


Fig. 8—Motor disconnecting switch

While denying that suspended particles are the cause of the blue color of water, Spring[20] recognizes the important part which they play in the color phenomena.

"One might think that the blue color of water would be sufficient in itself to account for the blue color of the Atlantic, the Mediterranean, and certain lakes; but this is not so. The action of water on the different components of white light varies very much. It absorbs the red strongly even in thin layers but it absorbs the other colors to some extent. If one were to examine the solar spectrum after sunlight has passed through an ever-increasing thickness of pure water, one would find the red, the orange, the yellow and the green disappearing successively and finally the blue when the thickness of the layer was sufficient. The light of the sun would therefore be absorbed completely in absolutely pure water if the water were deep enough. Such water would therefore appear as black ink. Can such a depth of water be realized in nature? Some years ago Fol and Sarasin[21] made some new experiments to complete work begun by Fol and others, in which they showed that daylight does not penetrate more than two hundred metres into the waters of the Lake of Geneva even in calm weather and in the month of August. They proved this by lowering to different depths in the lake a special apparatus containing photographic dry plates with a rapid bromide emulsion made by our countryman Van Monckhoven. Those plates which were lowered 237-300 metres showed no effect of light when developed, whereas at 170 metres the illumination was apparently about equivalent to that on a clear but moonless night.

Fig. 10—Steam-limit speed and field-control levers and interlocks, U. S. S. New Mexico

"Depths of more than two hundred metres are the rule not only in the ocean but also in most lakes. Consequently these deep waters, from which the light should never return, ought to appear absolutely black to us. Their surface might send back some reflected rays just as ink will; but the mass of the liquid ought not to appear colored if it sends back no light. Along the shores and in the shallows the blue color might show because the conditions would be more or less favorable for the daylight being reflected to the eye. The real phenomenon is quite different. The deepest waters are the bluest and in the shallow waters the blue gives way to green or even to yellowish-green and brown. How are we to account for this? . . .

"Tyndall has shown that no natural water is optically empty. Even after standing a long time the water of the Mediterranean and that of the Lake of Geneva scatters a beam of light. We therefore see the natural blue of certain seas and certain lakes because the daylight does not penetrate far enough into them to be absorbed completely. It encounters myriads of particles of foreign substances which reflect it in all directions like a multitude of microscopic mirrors. The effect to the observer is the same as though he were looking through a very thick layer. From this it follows that in a very deep and very clear lake containing relatively few suspended particles, a beam of light would penetrate further than into a more turbid water before all the rays would be reflected back. This clearer water would be a deeper blue and we find actually that the dark blue waters emit less light. It is also easy to explain the variations in the quality and intensity of these waters with sky changes or with varying agitation of the surface. . . .

"If the suspended particles are relatively numerous, a beam of incident light will not be reflected often in the water before melting the particle which will send it out. The blue will therefore not be saturated and will contain much white light. If the particles are few and far between, the beam will pass through a longer route in the water and the effect will be the same as though the observer were looking through a greater thickness. The blue will be more saturated and a deeper shade. In consequence of these multiple reflections the apparent illumination of the water does not necessarily come from a very great depth. The phenomenon is like that observed by all tourists in the mountains who have crossed freshly-fallen fields of snow consisting of the original small crystals which have not yet agglomerated to larger grains. Each hole made by sinking the point of the ice-axe in this snow is illuminated by the most beautiful blue light. This blue does not come from the depths of the ice or the snow but is due to the fact that a ray of white light has been reflected a million times more or less from the surfaces of the little snow crystals before reaching the eye of the tourist. At each one of these reflections from a blue substance it has lost some of the reddish light and consequently appears more and more blue. This explains why the waters of some mountain torrents are a beautiful blue, the intensity of which seems out of proportion to the depth of the water. The Ticino gives a series of illustrations of this between Airolo and Bellinzona. This explains why a light object, like an oar for instance appears blue when plunged a little way into the water of a blue lake, even though the layer of water covering it is not itself sufficient to show the

(*Continued on page* 414.)

[20] Bull. Acad. roy. belg. 1886, *12* (3), 814.
[21] Comptes rendus, 1885, *100*, 991.

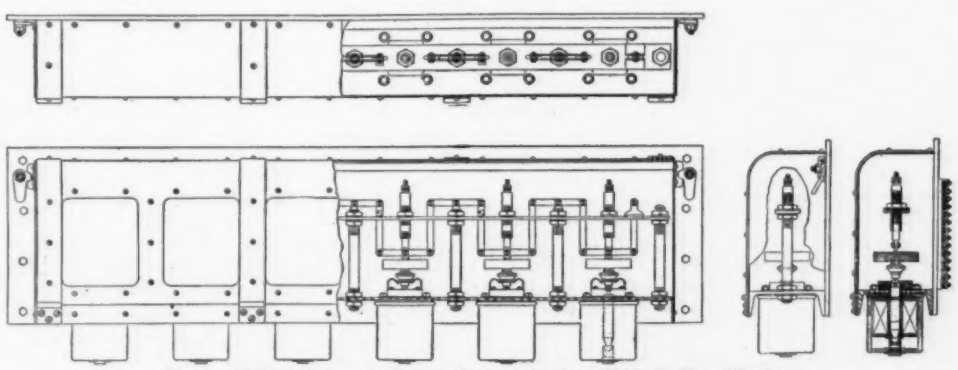


Fig. 9—Balance relays and operating mechanism, U. S. S. New Mexico

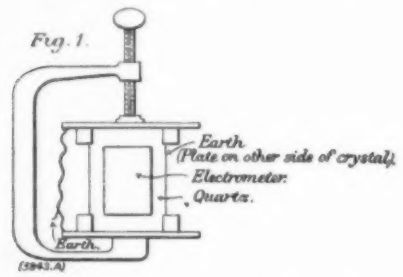
Piezo-Electricity and Its Application*

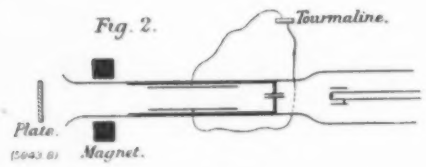
Tourmaline Crystals Aid in Analyzing the Nature of Explosions

By Sir J. J. Thomson, O.M., P.R.S.

Not many probably of those who attended at the Royal Institution on Friday, April 11, 1919, to hear Sir J. J. Thomson, O.M., P.R.S., discourse on "Piezo-Electricity and its Applications," knew much more about the subject than that the late Professor Curie discovered piezo-electricity in 1883, long before his work on radioactivity, and that piezo-electricity never acquired even a modest fraction of the popularity of the latter science. Piezo-electric crystals develop electric polarities when heated. Curie discovered that they also did so when exposed to pressure; he studied the laws of piezo-electricity, and W. Voight wrote a book on the theory of this intricate branch of electricity and crystallography, which attracted a small number of scientists, but which certainly did not promise to develop technical application. None but the initiated in Sir Joseph's audience could have known what line he would take, and his "Applications" came as a surprise.

In his introductory words Sir Joseph remarked that though electricity now dominated all science to a great extent, that electric phenomena, unlike those of light and heat, did not obtrude themselves on our attention; they were so "shy." Electricity owed its name and the science of electricity its origin to the





Devices for developing and employing piezo-electricity

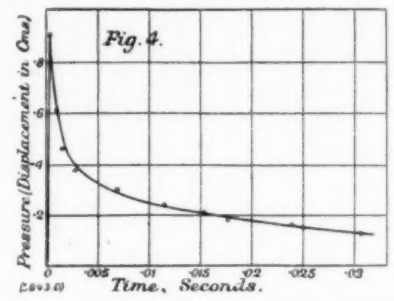
apparently trivial peculiarity that rubbed amber attracted small light bodies. To that property the phenomena upon which he wished to discourse might likewise be traced back. In 1703, it was said, a Dutch jeweller heated tourmaline crystals on embers—it might be interesting, Sir Joseph interposed, to know what the man was searching for. He discovered that light particles stuck to the crystals when cooling. That was long before the days of our distinguishing two kinds of electricity or knowing that there were such things as electric currents. The discovery was not published; but an anonymous German pamphlet of 1707 gave an account of the observation under the title "Curious Speculations in Sleepless Nights," and from that time tourmaline became known as the electric stone or Ceylon magnet. The discovery probably went back much further, however. Pliny alluded to the mineral "carbunculus" which attracted light bodies after exposure to the sun's rays or when rubbed, and Poggendorff had suggested that Pliny's carbunculus might have been tourmaline. Sir Joseph then demonstrated the way in which these phenomena were studied. He heated tourmaline crystals in a gas oven, took them out and dusted them with the mixture of red lead and sulphur which Lichtenberg used to distinguish positive and negative electrification. The mixture was shaken and dusted upon the cooling crystals through muslin, when by friction the yellow sulphur became negatively electrified and the red lead positive; it was seen that the yellow particles adhered to the one end of the crystal which had therefore acquired a positive charge by the change of temperature, while the red particles adhered to the other end, which was therefore a negative pole. The positive pole turned into a negative pole when the temperature was rising instead of falling.

*From *Engineering*.

Tourmaline crystals, Sir Joseph proceeded to demonstrate, also possessed peculiar optical properties. Two crystals arranged with their optical axes parallel to one another allowed the beam of polarised light to pass, but stopped it when crossed. The pyro-electric property first demonstrated varied much in different crystals. It was associated with elongation and contraction, and Curie had made the great discovery that tension and compression had the effects of heating and cooling respectively. A squeezed tourmaline behaved electrically like a cooling crystal. To distinguish the various phenomena this electrification called forth by pressure was designated piezo-electricity; but pyro-electricity and piezo-electricity were probably of the same nature. Most tourmaline crystals formed prismatic columns terminated at the top and bottom by complex hemihedral faces; the ends were not symmetrical, as might be expected from the fact that they showed polarities. In tourmaline [complex hydrated boro-silicates of aluminium, alkali metals, magnesium and iron] the principal axis ran from top to bottom, and for experimental purposes the slabs should be cut along planes at right angles to that axis. Quartz was also useful for this purpose; in that case the slabs should be cut at right angles to one of the three axes represented, in a hexagonal cross-section of a quartz crystal, by the three diagonals. There was considerable difficulty about finding good specimens. Quartz in particular was very prone to twinning, and two twins were always doing the opposite thing so that, when tests were made on a crystal from point to point, the effects balanced one another, and there was no uniform effect over an extended area. Tourmaline was not so bad in this respect, and crystals valueless as gems might be quite serviceable; but some black crystals were fair conductors of electricity owing possibly to the impurity which made them black.

In order to demonstrate the piezo-electric effect Sir Joseph placed a piece of brass foil on a tourmaline slab and joined the foil to an electrometer; a weight was then put on the foil and pressed down by hand; the electrometer was deflected to the right. That deflection might also be due to frictional electrification; when the plate was turned upside down, however, the deflection was to the left. Quartz gave the same effect. But in another respect tourmaline and quartz differed. Tourmaline only showed polarity when pressed normally to the surface, not when the pressure was on the end faces, lateral, parallel to the surface. Quartz displayed polarity in both these cases, and the two polarities were of the opposite kinds. The difference became very important when the plates were exposed to uniform hydrostatic pressure. There quartz gave no effect, because the positive and negative electrifications neutralized one another, unless we shielded the ends so that the pressure was unidirectional. With tourmaline the effect was observed under hydrostatic pressure, because end-pressure did not give rise to any electrification. The laws of these effects were studied by Curie, and he found that the quantity of electricity developed was just proportional to the pressure. The effect did not depend upon the thickness of the plate, and a pressure of 1 atmosphere developed in quartz 1/16 electrostatic unit of electricity per square centimetre of surface; the value of tourmaline was a little smaller. But individual determinations had to be made for each crystal or plate separately; Fig. 1 illustrates the apparatus used for this purpose.

If, then, Sir Joseph continued, the quantity of electricity was directly proportional to the pressure, we could measure pressure by measuring the quantity of electricity. That might not appear worth our while. But when in the explosions in guns or engines the changes developed with extraordinary rapidity, the whole explosion only taking 1/30,000 or 1/50,000 of a second, the interpretation of mechanical pressure determinations became very doubtful, and electric methods offered decided advantages. The principle of the application of piezo-electricity which he was going to describe was explained by the diagram Fig. 2. Supposing we exposed a crystal to the explosive pressure to be measured. We applied metal foils to the two crystal surfaces and joined them to two metallic plates mounted in a vacuum tube; the pressure electrified the plates and an electric field was set up between them. Now let a stream of electrons from a hot tungsten wire (heated by a battery) be propelled through a fine tube and through the space between the plates. As long as the plates were electrically neutral, the electrons would move in a straight line and would hit the screen or pohtographic plate at the end of the apparatus in a central spot; as soon as the plates were electrified, the upper one turning positive, *e. g.*, the stream of electrons would be deflected upward, and the distance between the two spots, the central spot and the deflected spot, would be proportional to the pressure. We could shoot particles at 6,000 miles per second; with an electric field, 1 in. in length, the particles would not occupy more than one hundred-millionth of a second to pass through the field. Thus we should be able to measure the pressure corresponding to this very short space of time. We could not, however, by these means alone obtain a pressure-time curve. An exposure of one hundred-thousandth of a second would



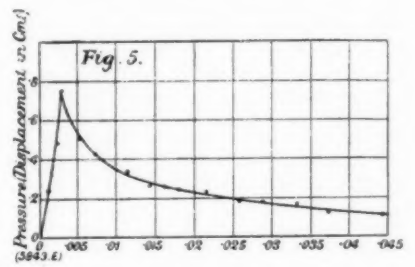


FIG. 6.

Pressure-time curves obtained by means of tourmaline exposed to pressures resulting from explosions

suffice to excite the photographic plate, and we might obtain a pressure-time curve by moving the plate or by dropping it. That would be a rather clumsy device, and very difficult, moreover, to work in a vacuum. It would be easier to move the stream of negative particles which could be deflected by magnetic force. When we placed an independent magnetic field beyond the electric field, there would be superposed on the deflections, say in the horizontal direction, by the electric force, a deflection in the vertical by the magnetic force. If we used a rapidly alternating magnetic field, the spot formed by the cathode rays would move up and down in a vertical line, if there was no pressure, on the crystal. When the crystal was under pressure, the spot would undergo a horizontal deflection and would travel along a curve, giving a pressure-time curve, as indicated in Fig. 3 (omitted).

In this reproduction of a photograph some curves can be seen above a horizontal band of light which itself is made up of a series of crowded zig-zag lines. The spot marking the moment of explosion, Sir Joseph explained, was in the left lower corner of the diagram; the pressure rose rapidly at first to a maximum and then fell off gradually, the spot describing a series of zig-zags; the reversals, first on the right-hand side, then on the left, and again on the right,

&c., were due to the reversals of the magnetic field. In interpretating the curves one important factor had to be borne in mind. The vertical speed of the spot was not uniform, but varied harmonically like a pendulum oscillation, and equal vertical intervals did not correspond to equal intervals of time. The two intervals were, however, connected by a simple relation, and a time-pressure curve could easily be obtained from the photograph; we had to analyze the curves. Fig. 4 (like Fig. 3) represents the explosion, in an airtight vessel of brass, of hydrogen and oxygen in the proportions of electrolytic gas, 2 volumes of hydrogen to 1 volume of oxygen. The initial gas pressure was 1 atmosphere, 76 cm. of mercury, the total gas volume was 765 cu.cm.; the ordinates marked the displacements of the central spot in fractions of a centimetre, the abscissæ measured the time in fractions of a second; each square of the diagram corresponded to one two-thousandth of a second. Fig. 4 showed that the maximum pressure was reached within a very small period, one sixteen-thousandth of a second in fact, and then fell off almost in accordance with an exponential law. When a trace of air was added to the gases, at slightly reduced pressure, the rise was slower and the maximum displacement was only 0.8 cm. (not 0.9 cm. as in Fig. 4); in the presence of a considerable proportion of air the rise to the maximum—as shown in Fig. 5—took one four-hundredth of a second, and the maximum displacement of 0.8 cm. was barely reached; a displacement of 1 cm. was equal to a pressure of 220 lb. per square inch. In these experiments an Eversheld-Vignoles constant potential high-tension dynamo was used for exciting the cathode rays. The magnetic field was produced by an alternator giving 30 alternations per second; to open out the timescale further the number of alterations might be increased many times.

By the aid of these indicator diagrams new light might be thrown on explosion phenomena, important industrially as well as scientifically. We wanted further information on the powers and time-constants of high explosives, and on the explosive phenomena in guns and in internal-combustion engines, also the effects of different kinds of petrol, of mixtures with air and other gases in various proportions, and of the sparks of the magnetos. We also needed much more information than we possessed about the explosions of different gases, such as hydrogen and oxygen, hydrogen and chlorine, &c. We could, by the aid of the piezo-electric method further observe the actual propagation of an explosive wave through tubes by putting one crystal in the one part of a tube and a second crystal in the other. In the same way we might also investigate the propagation of an explosive wave through a thickness of a solid, to the upper and lower surfaces of which we attached crystals. The last slide, Fig. 6, which Sir Joseph exhibited, proved that these things were not merely in the air. The diagram illustrated, he explained, the explosion of a charge of guncotton in sea water. The first curve, on the left, marked the direct explosion pressure; what the hump in the descending branch of the curve indicated Sir Joseph could not say; the second, less high curve, marked the pressure produced by the reflection of the wave from the bottom of the sea. It would be seen that the scale of this diagram was much more open than that of Figs. 4 and 5, and considering that circumstance, the absence of wriggles was noteworthy; a displacement of 1 cm. marked a pressure of 650 lb. per square inch. Knowing the distances involved the actual rates of propagation could be deduced.

Concluding, Sir J. J. Thomson remarked he hoped that the method described would be useful in many directions, and that the supply of tourmaline necessary for the continuation of these researches would not fail. Cane sugar might answer as a substitute for tourmaline, but it was too brittle; quartz was mechanically stronger than either of these materials. In his final words Sir Joseph expressed his indebtedness to Mr. D. A. Keys, of Toronto, and to Mr. E. Everett, his assistant at the Cavendish Laboratory, for the way in which they had developed these researches.

Paper Woven Goods in Austria-Hungary

In Austria-Hungary during the war the use of cotton was prohibited in the manufacture of oil-cloth, bookbinders' cloth, sacks, canvas packing-cloth, awning, carpets, upholstery and cushioned seats for railway carriages. For the manufacture of such goods only paper yarn was permitted. The restrictions are now removed. But paper has proved itself to be so good a substitute for cotton for such uses that it is likely to retain its ground to a large extent.—*Zeitschrift für angewandte Chemie.*

Improved Lighting by Street Lanterns

By F. Brueggeman

Street-lighting installations in which lantern-type fixtures are mounted on post standards ordinarily give distribution of light like that shown in Fig. 2 because the rays from the lamp are reflected uniformly in a circular area and as a rule are uncontrolled. Experimental work which has been carried on in connection with one of the larger installations of lantern-type street lighting has shown that it is possible to modify certain fixtures in order to secure better distribution of light like that shown in Fig. 2 (below). The result is accomplished by collecting the upward and downward rays from the incandescent lamp and reflecting them into useful directions preferably parallel with the street or drive.

The apparatus which was used in this experimental work has been operated on city streets. It is shown both assembled and disassembled in Fig. 1. In this photograph *A* is the upper reflector, which, when the

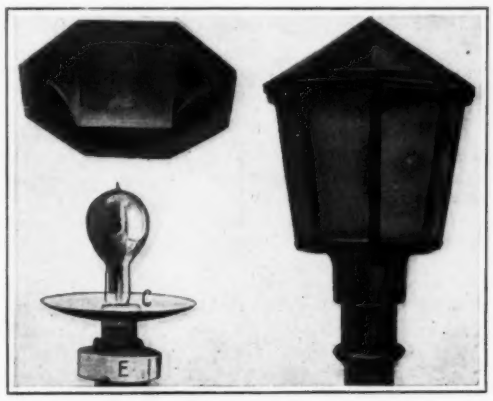


Fig. 1—Upper reflector A sits closely over lamp B; C reflects vertically against A

unit is asembled, sits closely over the series tungsten lamp *B* and reflects all direct rays, as well as reflected rays from the lower reflector *C*, into useful directions. The lower reflector *C* is parabolic and is designed to reflect vertically against reflector *A* all rays that srike it. *D* is a porcelain series socket of standard manufacture which fits into a specially designed porcelain combination cable terminal and receptacle *E*. The lead-covered cables terminate in this specially designed receptacle to make a safe and lasting installation. The complete lantern is constructed entirely of cast iron and glass, including the reflectors, which are white, fire-enameled and not affected by heat or

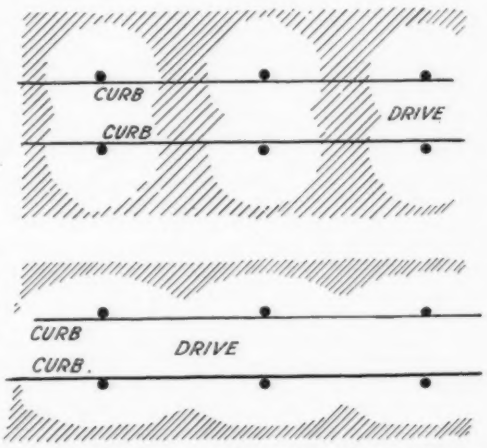


Fig. 2—Reflector A changes the light distribution of the street lantern from the upper curve to the lower curve

rough usage. Chipped glass is used in the lantern because it eliminates glare and does not offer much resistance to the rays. A broken glass panel in lanterns of this design may be readily replaced by merely tipping over the hinged top, pulling out the broken glass and sliding the new panel into place.—*Electrical World* (New York).

Winds and the Transatlantic Flight

From meteorological data obtained both on the American and the European sides of the Atlantic it is possible to specify with moderate certainty the conditions that would confront a pilot attempting a transatlantic flight, to indicate approximately what course should be followed, and which heights are the most favorable. In 1905-07 four expeditions were undertaken for the purpose of exploring the atmospheric conditions in the inter-tropical regions of the Atlantic. By measurement of the speed and direction of ascent of balloons from the deck of a yacht, the velocity and direction of the wind up to 30,000 ft. was determined between 10° and 30° north latitude, and 60° and 40° west longitude during the summer months. In all 715 observations were taken: 74 per cent. of the winds at sea-level came from north-east, and this direction was more frequent than any other up to 10,000 ft. At 20,000 ft., east and south-west winds became most common, and at 30,000 ft. south-west winds were strong and frequent. The steady north-east Trade Wind blowing near the surface of the sea would be a distinct aid to a westward flight. These winds at sea-level vary from 10 to 15 mls.p.h., increasing to 25 mls.p.h. at 20,000 ft.

From these data it is concluded that a very favorable course could be taken in the summer at a height of 3,300 ft., starting from Boston in an east-north-easterly direction. From 30° West certain Manchester observations could then serve as a guide, for these indicate that at this point favorable winds from the north-west are prevalent, thus encouraging a change in the course to one almost due east, with London as an objective. Observations show that fair weather and few storms prevail over this route in summer, and it is high enough to be above the fog.—*Aviation.*

Finding the Apparent Angular Movement of the Sun Between the Solstices

An interesting experiment easily made is within reach of amateurs in the study of astronomy. This experiment was made by the writer. The problem was to find and record the apparent movement of the sun from the summer solstice, June 21, to the winter solstice December 21. It is well known that the sun is farthest north on the first date and farthest south on the second. The writer resorted to the following plan to find the tangle through which the sun moves between the dates named. The observations must be taken at sunrise or sunset. And the horizon must be level, unbroken by hills or mountains. The ideal for sunrise would be on the western shore of a body of water, and for sunset on the eastern shore.

The writer chose sunset for observation, building an "observatory" as follows: A piece of 2-inch plank was used with one side well planed. This was set perfectly level on a solid support. A circle was then drawn ten inches in diameter, and in the center a long thin nail was driven perpendicularly, and it was ready for use.

At sunset, June 21, the first observation was made when the sun was farthest northwest, casting the shadow farthest southeast. Where the shadow crossed the circle a pin was stuck and with a straight edge a line was drawn to the center and marked with the date. It was the plan to take observations every two weeks, but sometimes owing to absence or to clouds it was impossible to do so, and the observations were irregular. When the sunlight was too weak to cast a shadow the bearing was taken by sighting on the sun from the opposite side of the circle, finding as near as possible the vertical line through the center of the sun. Then in line with the observation a pin was stuck in the circle and line drawn. The diagram will show the movement of the shadow northward until the winter solstice. On September 21 the whole angle is bisected and the shadow is pointing due east. On December 21 the last observation was taken, the "observatory" dismantled, and the diagram herewith made. It is not claimed to be mathematically correct with the crude instrument used, but illustrates the obliquity of the polar axis which accounts for the succession of the season. The whole angle measures 47 degrees, which means that the sun swings twenty-three and one-half degrees each side of the equator.

If the true meridian could be marked on the dial it would be interesting to measure the base angle on the dial when the sun is on the meridian on the 21st of June, September and December. The experiment can of course begin at the winter solstice and move in reverse order from the one here given.

Here is a fine experiment for budding astronomers, requiring no instrument whatever. Who will try it?

The total angle referred to by the writer of the above note is 47° only when the observer is at the earth's equator. At other latitudes the angle is greater. At latitude 66° 33′ it becomes 180° and to observers farther north than latitude 66° 33′ the sun does not set at all when near the summer solstice, nor rise at all when near the winter solstice—*Pop. Astron.*

The Color of Water

(*Continued from page 411*)

blue. The light reflected back by the object has not only traversed the slight depth between it and the surface, but comes also by reflection from the sides and is therefore blue.

"If the interal distances are not sufficient, as is often the case near the shores of a lake or a sea, the phenomenon becomes complicated. The light coming from these points will necessarily be less saturated with blue even though the bottom is white. Since water absorbs most readily the least refrangible or red rays, and then the others less and less completely up to the blue rays, the less refrangible rays will not be cut off in a thin layer of water and the light will appear green. This is probably the reason that the waves of the blue sea appear green. One really sees them by light transmitted through a relatively thin layer."

In a later paper Spring[32] points out that an optically empty water may appear blue when seen from above if the temperature of the liquid is not homogeneous. A column of water unequally heated is equivalent to a light fog if the tube is short and to a dense black cloud if the tube is long enough. "The light is reflected and refracted from the layers of unequal density and is scattered irregularly in all directions as though the liquid contained infinitely small particles. In other words such a medium does not behave like an optically empty one. This is important for the illumination of clear natural waters. A lake of pure water will appear blue if there are convection currents in it. The presence of solid particles is not absolutely necessary. If the convection currents are infrequent the lake will appear much darker, even though there has been no change in the chemical composition of the water. This is true experimentally. Forel[33] points out that the soft-water lakes are more transparent in winter than in summer. This is because in summer there is a greater difference between the temperatures at the surface and in the depths. In consequence of agitation due to many causes, the layers of water of different density do not remain stratified one above the other in a regular manner. They mix and convection currents are produced in all sorts of directions scattering the light every which way. Forel has observed that during the summer months it is absolutely impossible to see the bottom and to detect the ancient objects which one looks for in the ruins of the lacustrine cities at depths of 3-6 meters. In the winter the water is usually transparent enough to make the search profitable."

[32]Bull. Acad. roy. belg., 1896, *31* (3), 94, 256.
[33]Arch. Sci. phys. nat., 1877, *59*.

Advance in the Design of X-Ray Tubes

THE Coolidge X-ray tube operates at extremely high vacua with a pure electron discharge, as contrasted with the Röntgen tubes formerly constructed depending in their action upon the ionisation of a residual gas. In one of the modifications of this tube the kathode rays are focused by means of a static focusing device, such as a ring tube, or other conductive member surrounding the kathode and establishing a static field radially about the kathode. The focusing member appears to become statically charged by the electron emission of the kathode, and thus modifies the static field in the tube, which is controlling the motion of the kathode rays. Langmuir has designed a tube wherein the length of the focus of the kathode rays is varied at the will of the operator, thus controlling the area of the focal spot or surface by adjusting the distribution of potential in the static field, directing the kathode-rays inwardly to a common point or outwardly from a virtual focus. By means of a source of potential between the kathode and the focusing device, the intensity and polarity of the static field may be varied in a manner here fully described with the aid of diagrams. When the focusing member is connected to the kathode without interposing any source of potential, one of the surfaces which may be plotted in space to include points of the same potential, will include the tip of the filament and the outer edge of the focusing tube. As such equipotential surfaces approach the anode they become less concave. The electrons emitted by the filament when travelling from the kathode to the anode, tend to move perpendicularly to these equipotential surfaces, and are thus directed toward a spot of restricted area upon the anode, called the focal spot. When a source of potential is introduced into circuit between the kathode and focusing member, the positive terminal being connected to the focusing member, the shape of the equipotential surfaces will be changed, as the tip of the filament and the rim of the focusing member no longer are at the same potential. By making the positive potential high enough the focusing of the rays may be entirely prevented, that is, the rays will diverge instead of converge. By making the potential negative with respect to the focusing tube the focal area may be made smaller, or, in other words, sharpness of the focusing may be improved. The charge on the focusing member also has an effect on the resistance of the tube and hence on the hardness of the X-rays. A positive charge decreases the hardness, and a negative charge increases the hardness in proportion to the potential of the charge.—*Science Abstracts.*

Speed Measuring Instruments for Aeroplanes

THE conclusion of an article on speed measuring instruments for aeroplanes and airships first describes a double indicator which shows the revolutions per minute of both the right and the left hand driving motors. The two speed cards are in one case and are clearly marked from four to sixteen hundred r.p.m. In this casing is fitted the magnetic coil which itself carries the indicators, so that all gearing is avoided, the movement of the indicator needle being limited to an angle of 90°. The needle for the L.H. motor moves underneath the needle of the R.H. motor, and the reading especially on the higher numbers is very clearly seen.

In spite of their simplicity these double speed indicators have not come into general use, their disadvantages being that if a spedometer has to be changed the whole apparatus must be taken to pieces.

The anemotachometer is another important instrument for aircraft, for measuring the actual or relative speed of the flying machine. It is made in the form of a cross, each arm of which carries a cup-shaped impeller which the wind drives. The rotation of the wind-driven impeller on its central spindle actuates a pendulum movement, the strokes of which are transmitted to the indicating dial. One of the greatest advantages of this instrument is that its action is always positive and is not affected by the density of the air through which the aeroplane is passing and, further, that the anemotachometer comes into action immediately the machine starts.

As this instrument has to be near the driver's seat, in large flying machines the same four-cup cruciform anemotachometer is used, but in this case the control is electrical and the flying speed is given by the voltmeter above the pilot's seat. This instrument has a second valuable use in that from it the pilot can judge the curvature of his course. Owing to the number of motors which are now included in the design of one aeroplane, steering has become very difficult, and it is often impossible for the pilot to know in foggy weather whether he is steering in a curve or straight forward. If two anemotachometers electrically connected to a central voltmeter are placed towards the extremity of each wing of the aeroplane, then the indications of both instruments will be the same if the machine is flying straight, but if flying in a curve the instrument on the inner or shorter radius of the curve will register a slower speed than the one on the outer radius. From the difference between these indicated speeds, the curvature can be seen from a properly prepared chart on the indicator dial.

The article is concluded by a description of various ways in which the anemotachometer may be used and different methods of the electrical wiring of the instrument, with various graphs and diagrams to illustrate the text.—*Wilke, Der Motorwagen.*

Metal Strapping on Wooden Boxes

ONE of the quickest and cheapest methods of adding to the strength of a wooden box is to wrap it with thin, flat metal straps. The ability of a box to withstand the hazards of transportation may thus be increased several hundred per cent. Tests made at the Forest Products Laboratory for the War Department have provided some information as to how a box should be strapped to add most to its durability.

The best place to apply the strap is apparently about ¼ of the length of the box from the end. The strapping is preferably nailed at each edge of the box to hold it in place, having, of course, been drawn snug by special tools for that purpose. Nailing the strap in place works well on boxes made of lumber ½ inch or more in thickness, but cannot be successfully used on thinner material because the nail splits the board. On thin boxes it is necessary to join the two ends of the strap (for which purpose there are several devices), thus making a metal band around the box held in place by tension.

Depending on tension alone to keep the strap in place is, however, open to one serious objection. Unless the box is constructed of dry lumber, shinkage reduces its circumference to such an extent that the metal strap is no longer tight. This action not only reduces the effectiveness of the strap, but commonly permits it to slip over the end of the box. A shrinkage in moisture content of 10 per cent. will permit the straps to fall off when the boxes are subjected to the ordinary hazards of transportation. A shrinkage of 5 per cent. will loosen the straps considerably, but the shrinkage is rarely enough to permit them to fall off.

The effect of shrinkage of the box is also serious when the straps are nailed at any point, since it causes them to buckle or "festoon." The reinforcing effect of the straps is thus diminished and the box becomes dangerous to handle. It is important, therefore, that metal-strapped boxes which are to be in transit or storage for any length of time should be built of dry lumber.—*Chem. and Metall. Engineering.*

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Table of Contents

	PAGE
Mechanics of Earthquakes.—By C. Somigliano	402
Emergency Seasoning of Sitka Spruce.—By L. A. Welo	404
Different Types of Airships (with frontispiece)	405
Economics of Transportation in the Mississippi Valley.—By J. R. Bibbins	406
Electric Propulsion for the *New Mexico*—III. Main Control Equipment.—By C. T. Hentschel	408
Color of Water—III.—By W. D. Bancroft	410
Piezo-Electricity and Its Applications.—By Sir J. J. Thomson	412
Paper Woven Goods in Austria-Hungary	413
Improved Lighting by Street Lamps.—By F. Brueggeman.	413
Winds and the Transatlantic Flight	413
Finding the Apparent Angular Movement of the Sun Between the Solstices	413
Advance in the Design of X-Ray Tubes	414
Speed Measuring Instruments for Aeroplanes	414
Metal Strapping on Wooden Boxes	414
Plywood in Aeroplane Construction	415
Application of Kirchoff's Law	415
Discharges of Atmospheric Electricity	415
Index	415

Plywood in Aeroplane Construction

THE first point upon which stress is laid in this article, describing the many uses to which plywood may with advantage be put, is that the idea of a number of sheets and fragments of thin wood stuck together by an adhesive such as ordinary glue, more or less soluble in water, or swelling and loosening on exposure to atmospheric humidity, should be dismissed from the mind when the material "plywood" is under consideration.

True plywood is a product resulting from a scientific process involving a correct and methodical sequence of operations all depending on each other. The elements of the original structure of the wood; the relations of the particular cementing material employed to the wood and to the atmospheric conditions of the moment; the temperature required to produce the chemical reactions between the wood and the cementing material, and within the cementing material itself; and the magnitude and duration of the pressure applied per unit area; all these form such a number of variables that no routine standardisation is practicable, and only the exercise of individual skill obtained under long experience, can produce a determinate result.

Laminated plywood formed into shapes under heat and high pressure with cementing materials which become insoluble in the course of the process, has been used in Russia for many years, notably in the works of the Russian Baltic Wagon Co., Ltd., who made the plywood fuselage of the first Sikorsky aeroplane. From Russia the use of plywood extended to Germany in the products of the Deutsches Rohrplatten Gesellschaft; from which a knowledge of these special processes and equipment passed to the United States nearly twenty years ago. In Russia Capt. Kostovitch used plywood for dirigibles which in construction and design anticipated the most recent rigid plywood dirigibles built by the Schutte-Lanz Company in Germany. In Russia also the first complete plywood aeroplanes were made by Steglau in 1912, the use of plywood extending even to the wing covering.

In France, as early as 1909, sheet plywood was used by Levavasseur, and later, in 1912, Béchereau, of the Deperdussin Company, designed the fuselage now known as the "monocoque."

The Germans, who at first made fuselages of the truss type, covered in with linen after the prevailing French style, commenced about 1912—probably following on a visit of one of their investigators to Russia—to use plywood in fuselage construction, following not the method of Béchereau but a more correct method employing longerons and bulkheads.

England and France continued to use the linen-covered truss construction, and the designers of the United States in most cases followed the precedents thus created with little or no regard to what had been developed in Russia and Germany.

It is pointed out what rough usage the fuselage of the Albatross aeroplanes are able to withstand, and that the use of plywood on British and French machines is even yet unlike that of the better-constructed German aeroplanes in that the plywood is generally nailed on as a mere covering, and not made an integral part of the structure.

Among the advantages of plywood as against the truss construction are the facts that no periodical truing up is required, and that the wood for plywood being so thin may be dried very quickly. The real problem in its successful use in aeroplane construction lies in the standardisation of parts for quantity production.—*H. H. Suplee, Aerial Age Weekly.*

Applications of Kirchoff's Law

THIS is a short article giving some practical applications of the laws of Kirchoff. It is a simple matter by Ohm's laws to find the current passing through a circuit supplied from two or more equal electromotive forces and equal internal resistances connected in parallel. If on the other hand the two or more electromotive forces are unlike with unequal internal resistances and connected in parallel, Kirchoff's laws must be resorted to.

By Kirchoff's first law the algebraic sum of the currents meeting at any point is zero, and by the second law the algebraic sum of the products of the current and resistance of each part of a series circuit equals the electromotive force of that circuit.

If a generator has an open circuit voltage of $E_1 = 120$ volts and an internal resistance of 0.2 ohms while a storage battery develops a voltage $E_2 = 110$ volts on open circuit and has an internal resistance of 0.3 ohms, both generator and battery being connected in parallel to an external circuit r^4 of 2 ohms resistance, it is impossible to tell by inspection whether the generator will charge the battery or the battery discharge through the external circuit r^4. This must be determined and also what the voltage across the circuit will be when the current is flowing.

If the battery is being charged the questionable current would have a negative value, indicating that the battery is aiding the generator by discharging through r^3. From the figures and formulæ given it is shown that this value is —1.898 amperes, and from this it may be calculated that the voltage $E = 109.436$ volts by three different methods which are given.

The same problem may be worked out by a different method, in which it is assumed that the generator current $= x$, and the battery current $= y$, then the current passing through the circuit $r^3 = x - y$. The working out of the problem by this second method is a check upon the first. The effect of armature reaction in reducing the generated voltage is not taken into account in the calculations given, but for an interpole machine the effect is negligible.—*Kubanyi, Power.*

Discharges of Atmospheric Electricity

THIS article deals with the records for Zurich and neighborhood of severe storms with thunder and lightning. The earliest observer was Wolfgang Haller, who kept records between 1550 and 1576; a later observer was Prof. Fries, whose records cover the period 1683 to 1718, and since 1821 official records have been kept, while since 1864 the meteorological office has published returns.

A table gives the results. The storms averaged 15.1 per annum for the period 1821-1840; 16.8 for 1841-1860; 16.4 for 1861-1880; 22.3 for 1881-1900 and 18.3 for 1901-1918. It had been suggested that the extended use of high tension conductors of electricity carried upon poles might have considerably modified the number of electric storms, but the author is satisfied that this theory is disproved by the official records. He considers that the seat of the atmospheric discharge is at far too great an elevation above the earth to be affected by electric conductors. He also points out that the percentage of deaths from lightning have remained practically constant.—*Schweizerische Bauzeitung.*

The Scientific American Supplement Index for Vol. 87

JANUARY—JUNE, 1919

THE * INDICATES THAT THE ARTICLE IS ILLUSTRATED

A

Abrasion-Meter *372
Acetic Acid 279
Acetylene Mine Lamps 149
Acid-Resisting Iron *340
Acoma Pueblo, N. Mex., Scenes in *152
Actinium, The Parent of 139
Adhesiveness of Glue 117
Aerographic Records, Uniformity in *15
Aeroplane. *See* Airplanes ....
Age of the Earth, The 34
Air Compressor Explosions 10
Airplane Construction, Plywood in 415
Airplane Accidents 30
Airplane Design, Trend of 11
Airplanes, Experiments With Tandem *204
Airplanes, Surveying and Mapping from 386
Airships, Different Types of *405
Alcohol, Asphodel as a Source of 27
Alcohol from Algae 153
Alcohol from Wood Pulp Refuse. 14
Alcohol, The Pharmacology of .. 22
Algae, Alcohol from 153
"All Wool and a Yard Wide" .. 262
Alpha Rays, Action of on Metals 94
Aluminum, Annealing 123
Aluminum Alloys, Some Zinc and 367
Aluminum Leaf, Use of in Waterproofing Wood *292
American and German Science .. 302
America's Food Resources *136
American Instit. Elect. Eng. Rules Applied to Motors 398
American Merchant Marine, The New ....I, 226, II,
Ammonia, Oxidation of *367
Ammonia, Reduction of the Oxides of Nitrogen to 91
Anemometry, Hot-Wire *106
Animals, Behavior of During Explosions 48
Animal Luminescence and Symbiotic Microbes 286
Ankylostome, Detection of 127
Anomalies in the Animal World XV, *85
Anthracite and Bituminous Coal, Burning Fine 391
Anthrocyanin Pigments in Plants, The 2
Antiscorbutic Principles in Limes and Lemons 57
Apple Beverages, European ... 205
Arizona, Canyon de Chelly Ruins in *100
Army, Water for an *36
Army Ant *228
Arsenic, Determination of, in Dead Bodies 94
Art Museum as a Laboratory .. 117
Artificial Silk, Formation of the Thread in the Spinning of 14
Asphodel as a Source of Alcohol. 27
Astronomy, Influence of on Human Thought 342
Atlantic Flight 38, 413
Atomic Hypothesis, Bohr's 176
Atomic Structure, Spectrum Analysis and 382
Attraction, Rôle of Forces Dominating 142
Australia, Grass Tree Resins of 137

B

Banana, Nutritive Value 139
Banana-Must, Alcoholic Fermentation of 233
Barberry, Eradicating the 11
Baseball, A Pitched *12
Behavior of Animals During Explosions 48
Beverages, European Apple 205
Bituminous Coal, Burning Fine Anthracite and 391
Blue Coal *156
Bohr's Atomic Hypothesis 176
Bone Grafts 239
Books Uncut, Called "Back Numbers" 189
Botany, Economic and Chemical Industry 63
Brass, Cadmium in 32
Brass, Corrosion of, in Seawater (P. T. Bruhl) 211
Brass, Electric Melting of 311
Brass and Alloys, Rapid Estimation of Lead in 231
Brewing, Couch Grass as Malt-Adjunct in 87
Bromide Prints, After-Treatment of 153
Bulk of Commodities 227
Burns by Caustic Soda, Treatment of 64
Butterflies, Influence of Color on 201
By-Product Coking, Recent Developments in 171

C

Cacao Production, Science in .. 165
Cadmium in Brass 32
California, Ocean Temperatures and Seasonal Weather in Southern (McEwen) 224
California, Water Power in (Palmer) *260
Camel, South American Relatives of *120
Cameras, Special, for Aerial Photography *60
Cameroon, Some Native Industries of *344
Canal in the Problem of Transportation *168
Canyon de Chelly, Ariz., Ruins in *100
Carbides, Formation and Stability 103
Cargo, Ship and—in One *383
Catalyst, Rôle of 164
Cattle, Saving Our *328
Cattle Tick, Fight Against ... 266
Cedars of Lebanon (A. Henry). 295
Celebes Ore Deposits 373
Cells, Sizes of 341
Cellulose and Derivatives, Fluorescence 144
Century Plant in Mexico 313
Changes of Ocean Level (W. M. Davis) 294
Charcoal, Manufacture of From Waste *124
Charcoal, Spontaneous Explosion of, in Liquid-Oxygen Containers 52
Chemical Combination, Molecular Association and (F. Michaux) 247
Chemical Reaction, Rôle of Ultra-Violet Light in 208
Chevrons, How They Are Made. *116
Coal, Nitrogen Content of Oxidized 106
Coal Gas for Motor Vehicles in England 10
Coatings, Metallic, Production of 112
Coconut Palm (P. J. Wester) .. *276
Coin Problem, A Scientific (T. L. DeLand) *220
Coke, Conditions for 101
Coking, Recent Developments in By-product, in England 171
Collecting, A Tip in Pond 71
Collision Predictor (Joly) *334
Colloid State, Significance of ... 182
Colloidal Fuels (Submar. Def. Assoc.) 338
Colloidal Membrane in Osmosis. 199
Color, Function of in Organisms. 102
Color, Influence of, on Butterflies 201
Coloring Matter of the Glumes of Sweet Sorghum, Industrial Applications of the 26
Comets, Origin of 206
Combustion in Hay, Spontaneous 94
Complexes, Inorganic (Mourelo) 258
Compressibility of Solids at High Pressures, Determination of 347
Concrete as a Chemical Engineering Material (M. Toch). 339
Concrete, Effect of Water on Strength of *211
Concrete Articles, Making Hollow 4
Concrete Ships as Carriers 101
Contraband Trade Between Switzerland and Germany ... *52
Conveyor, Portable Scoop *264
Copper, Metallurgy of (T. H. Eastdick) *332
Copper, Cold Work on 91
Copper, Process for Sulphate of. 108
Copper, Production of *72
Copper Castings, Strontium in. 173
Copying, Photographic 128
Cotton, Testing of, by Steaming 224
Cotton and Jute, New Substitute for 96
Couch Grass as Malt-Adjunct in Brewing 87
Covering Power and Illuminating Power of Lenses: Tests and Performance (C. W. Piper) 351
Crane, Safety of the Alternating Current 62
Crystals, Apparatus for Growing, Under Control (Hostetter) *264
Crystals, Behavior of—in Liquid Air 197
Crystals, Phototropy in *80
Crystallography, Molecular Orientations in Physics and I, 18; II, 46
Cultures, Diffraction Phenomena of 116
Cumarin, Tonka Beans and 78
Currents, Undamped, in "Super-Conductors" 71
Cutting Lubricants 350
Cyphocrania Gigas (Fouchier). *360

D

Dangers of Explosion, The 7
Desert, Trees for *188
Dew-Gauge, Ereida's *373
Diesel Engine, Marine 230
Diesel Engine on Locomotives .. 78
Diffraction Phenomena of Bacterial Cultures 116
Diffusion, Principles of and Their Analogues 31
Diplopia, Prism Binoculars for Detecting 240
Direct Current vs. Power Factor (F. E. Austin) *316
Disinfection by Alcohol, Theory and Practice of 103
Disinfection by Heat 203
Dispersoidology 182
Dissociation, Spectroscopy and. 48
Dock, Docking a 128
Duct Keel in Sea-Going Steamers, The 16
Dustfall of March, 1918 (Winchell and Miller) *234
Dust in Mine Air, Estimation of by the Kotze Koniometer 6
Dyes, in Photography 6
Dye Industry, The German 27
Dye Process, A New Photographic Mordant 20

E

Earth, The Age of 34
Earth's Interior, Constitution of. 73
Earthquakes, Estimating the Distance of 284
Earthquakes, Mechanics of *402
Eggs, Photographic Method for the Examination of 64
Egypt, Manganese in 267
Electric Dog *376
Electric Propulsion for the U.S. S. *New Mexico* ....I, *356; II, *396; III, *408
Electrical Meter Testing in Germany 36
Electricity, Mechanics and *252
Electricity, Atmospheric 415
Electricity and Matter 355
Elements, Hackh's Classification of *146
Elemi, Porto Rico Gum 201
Embroidery by Wholesale *116
Emulsions, Making of Stable for Bacteria 75
Energy, Ultra-Violet (Luckiesh). 242
Engine, Marine, Internal-Combustion *140
Enlarging, Position of the Illuminant in, and Projection ... 351
Esperanto, History of 99
Evolution, Rôle of Selection in, I, 66; II, 90

Explosions, Air Compressor... 10
Explosions, Behavior of Animals During ... 48
Explosion, The Dangers of.... 7
Explosion, Spontaneous, of the Charcoal in Liquid-Oxygen Containers ... 52
Explosives, Utilizing Surplus.. 153
Exposure Meters ... 105
Eyepieces, Telescopic ... 107

F

Familiar Insects Through the Camera ... *248
Family, and Relations of Its Members in India ... 82
Fastness of Colors, to Light, Standardizing ... 57
Fat from Low Forms of Animal Life ... 64
Fatigue, Biological Character of ... 207
Faults, Locating Submarine... 237
Feed, Digestibility of Artificially Dried ... 221
Fertilizers, Agricultural ... *74
Fertilizers, The Theory of.... 26
Field, Influence of On Initial Phase of Discharge ... 371
Films, Lubricating and Other Properties of Thin Oily.... 170
Fishery Industries, Sea Lions and (C. H. Townsend) 328
Fishes Around New York 57
Flavoring Matters, Chemistry of ... I, 114; II, 134
Flowers, Whence Their Names.. 176
Fluorescence and Molecular Transformation.. I, 162; II, 187
Flying Sickness (Flack)..... 262
Food Substitutes and the Zoo.. 99
Forecasting, Ocean Temperatures in Long Range ... 166
Formalin, Effect of, on Germination ... 164
Freudian Theory of Psycho-Analysis Illustrated (E. Rignano) ... 326
Flowers and Tiny Animals in Glass ... *296
Fuel, Our Liquid ... *284
Fuels, Colloidal (Submar. Def. Ass.) ... 338
Fundamental Concepts of Physics ... 287
Fur Seal Problems and Their Solution, Two (G. A. Clark). 267
Furnaces Without Crucibles, Gas-fired Melting ... 126
Future State, Burial Customs and Belief in 84.

G

Gas for Motor Vehicles in England, Coal ... 10
Gas for Raising Steam ... 179
Gas Offense Preparation in the United States ... 180
Gases in Alloy Steel ... 235
German Commercial Trickery... 37
German Dye Industry, The... 27
German Merchant Fleet, Present State of ... ? 90
Germination, Effect of Formalin on ... 164
"Ghosts" in Prisms, Detection of ... I, *92; II, *108
Giant Insect (Fouchier) ... *360
Glass, Annealing of ... 152
Glass, Flowers and Tiny Animals in ... *296
Glass, How to Cut Properly ... 151
Glass, Iron as a Source of Color in Optical ... 239
Glass Industry, Refractory Materials and ... 329
Glass, Polishing ... 205
Glassware, Scientific ... 87
Glue, Adhesiveness of, Determined ... 117
Gold, at High Temperatures and Pressures ... 94
Grass, The Story of a ... 23
Gravel, Artificial ... 341
Gravitation, Rôle of Forces Dominating ... 142
Gun Metal, Impurities in 19

H

Hackh's Classification of the Chemical Elements ... *146
Hadfield Prize, The ... 313
Hawks of Canadian Prairie in Relation to Agriculture (P. A. Taverner) ... *212
Hay, Spontaneous Combustion in ... 94
Health, The Relation of Light to ... 4
Heat, Disinfection by..... 203
Heat Losses Through Insulation. 373
Heater, Electric, for Distilling Gasoline ... 107
Helium for Airships ... 391
Holland, Oyster Cultivation in. *164
Homing Habits of the Pulmonate Mollusk Oncidium 288
Hook-Worm Disease, Detection of ... 127
Hops in California, Growing (A. L. Dahl) ... *372
Horses, Work Done by, During the War in France ... 105
Human Thought, Influence of Astronomy on (H. MacPherson) ... 342
Hurricanes, Effects of, on Upper-Air Currents ... 189
Hydraulic Systems, Shock in.. 84

I

Ido, History of ... 99
Ignition Temperature of Gaseous Mixtures ... 55
India, Beginnings of the Language of Southern (J. Lazarus) ... 238
India, Family Life in ... 82
India Utilizing Native Timber.. 64
Indies, Tin Mining in the Dutch. 383
Indigo, To Make Liquid ... 144
Industrial Substitutes in Germany ... 325
Industry, Chemical and Economic Botany ... 63
Influence of Aviation Upon Mathematical Physics ... 341
Ink, Pigment for Printing.... 135
Inorganic Complexes ... 258
Insect Tyrants: The Army Ant. *228
Insects, Whence Their Names. 150
Insulation, Heat Losses Through ... 373
Intelligence, Estimating ... 87
Iron, Acid-Resisting ... *340
Iron as a Source of Color in Optical Glass ... 239
Iron, Cast, Wearing and Anti-frictional Properties of..... 186
Iron, Grey Cast, Preventing Growth in ... 128
Iron, Grey Cast, Growth in.... 37
Iron, Removal of, from Drinking Water ... 237

J

Japan, The Vegetable Oil Industry of ... 229

K

Kaolins, Sulphuric Acid in the Sedimentation of ... 160
Kirchhoff's Law, Applications.. 415
Kite-Flying, Meteorological.... 110
Kontometer, Kotze Estimation of Dust in Mine Air by the.. 6

L

Lamps, Acetylene Mine 14
Lantern, Improved Street.... *413
Latent Image, How Developed on Photographic Plates 240
Latent Images in Glass 240
Lateral Deviation of Projectiles ... 215
Laundering, Action of—Agents on Textiles ... 123
Laundering, Chemistry of *392
Lead Alloys ... 115
Lead, Compounds of ... 126
Lead, Rapid Estimation of in Brass and Alloys ... 331
Leather Preservation ... 55
Lens for a Studio ... 222
Lenses, Covering Power and Illuminating Power of: Tests and Performance (C. W. Piper) ... 351
"Life," Meaning of ... 133
Life, Organic Matter and 362
Life-Table, Biology of..... 160
Light, Measuring the Intensity of ... 133
Light Scattering by Air Molecules ... 196
Light, Scattering of by Dust-Free Air ... 185
Light to Health, The Relation of ... 4
Lime, Hydrated, in Mortar ... 84
Lime, "Tetraphosphate" ... 126
Limes and Lemons, Antiscorbutic Principles in ... 57
Line Subjects, Exposing on.... 80
Linen Plant Tags ... 48
Locomotive, Thermo (Diesel).. 78
Locomotive Service, Improved.. 128
Long-Range Guns ... 235
Lost City—New Mexico (C. D'Emery) ... *216
Louse, That Annoys Armies and People ... *229
Lubricants, Cutting ... 350
Lumber, Seasoning of..... 158
Luminescence, Animal — and Symbiotic Microbes (U. Pierantoni) ... 286

M

Macoa Indians of Venezuela, The ... I, *8; II, *24; II, *40
Magnetic Field of the Sun.... 293
Magnetism, New Theory of ... 186
Man, Equality of ... 126
Man, Pleistocene, of Vero, Fla.. 118
Manganese Alloys in Open-Hearth Steel Practice (S. L. Hoyt) ... 282; 302
Manganese in Egypt ... 267
Maori Burial Chests ... 67
Marbles of Italy, The ... 43
Marine Diesel Oil Engine (J. W. Anderson) ... 230
Marine Lighting, Recent Developments in ... I, 359; II, 388
Mass, Standards of ... 87
Matches, How Made ... *56
Mathematical Physics, Influence of Aviation Upon ... 341
Matter, Electricity and ... 355
Mechanics and Electricity.... *252
Megass, Paper-Making from.... 102
Meeting New Demands, Paint and Varnish Makers ... 390
Men, Conservation of, on Our Railroads ... 109
Mentality of the War Prisoner. 105
Menthol-Yielding Plant..... 53
Mesopotamia Minerals and Manufactures ... 397
Metal, Gun, Impurities in 19
Metals, New Process of Spraying ... 29
Metals, Super-Conductivity of, at Low Temperatures 381
Meteor, April 23, 1918 87
Meter, Double-Tariff Current.. 78
Metropolitan Museum as a Laboratory ... 117
Mimicry, Protective ... *85
Microscope, Anastigmatic Eyepieces for ... 73
Microscope in Metal Study (H. M. Sayers) ... 210
Mine Lamps, Acetylene 14
Mineral Elements in Animal Nutrition (E. P. Forbes).... 218
Miniature from the Past *324
Mint, Japanese Black ... 53
Mirrors, Reflecting Prisms in Place of ... *172
Mississippi Valley, Economics of Transportation in *406
Mixtures, Gaseous, Ignition Temperature of ... 55
Molecular Association and Chemical Combination (P. Michaux) ... 247
Molecular Orientations in Physics and Crystallography, I, 18: II, 46
Molecular Transformation, Fluorescence and ... I, 162: II, 187
Molecules, Life and Structure of (Amé Pictet) ... *50
Monel Metal ... 126
Moon, Motion of ... 100
Mortality Due to Snakes and Wild Animals in India 108
Mortar, New Elements in.... 84
Mosquitoes, Flight of Through Horizontal Pipes ... 186
Moss, Sphagnum ... 48
Motor, Continuous-Rated and Its Application ... 398
Motor, Wave and Tidal *156
Motor Fuel Problem ... 311
Motor Vehicles, Coal Gas for.. 10
Myopia, Causes and Prevention of ... 71

N

Negatives, Stripping for Storage ... 137
New American Merchant Marine (E. N. Hurley)..I, 226; II, 250
New Mexico, U.S.S. Electric Propulsion for..I, *356; II, *396 III, *408
New York, Fishes Around 57
New York Harbor, Salvage Work in ... *232
Newton and the Colors of the Spectrum (R. A. Houston).. *236
Nickel, Electro-Chemical Behavior of ... 135
Nitric Oxide, Stability of 91
Nitrogen Fixation, Atmospheric, in Japan ... 390
Nitrogen Fixation, Present Status of (A. H. White).... *330
Non-Inflammable Plastic Material ... 39
Nucleic Acid and Its Analytical Examination (A. C. Chapman) ... 356
Nutrition, Mineral Elements in Animal ... 218

O

Ocean Flying, What the Weather Man Thinks of (W. R. Gregg)..... I, *274; II, *300
Ocean Level, Changes of (W. M. Davis) ... 294
Ocean Temperature in Long-Range Forecasting (Brooks). 166
Oil, Determination of, in Seeds. 155
Oil, Lubricating, Substitutes for ... 119
Oil, Rubber-Seed ... 21
Oncidium, Homing Habits of the Pulmonate Mollusk (L. B. Arey and W. J. Crozier).... 288
Organic Matter and Life (J. Nycote ... 362
Osmosis, Function of the Colloidal Membrane in..... 199
Osthomyslenski's Method of Vulcanization Without Sulphur... 29
Overseas Flight, Ready for.... 229
Oyster Cultivation in Holland.. *164
Oyster Feeds Both Men and Plants, The ... *4

P

Pacific, Islands of, Importance of ... 98
Packing for Export (H. R. Moody) ... 366
Packing Goods for Shipment.. 138
Paint, Discoloration of White.. 91
Paint for Ship, Four Tons of Lead in ... 256
Paints, Luminous: Radium vs. Meso-Thorium in ... 272
Paint and Varnish Makers Meeting New Demands 390
Palate of Civilized Man and Its Influence on Agriculture. *68
Paper, Yellowing of (A. B. Hitchins) ... *222
Paper-Making from Megass... 102
Parabolic Mirrors, New Process for Making ... 275
Patent Rights, The Selling of (F. W. Harris) ... 303
Philosophy and Spiritualism.. 345
Phosphorus, Effect of the Qualities on Soft Steel 54
Photo-Copying Process, Playertype ... 271
Photographers' Hints for from Motion Pictures ... 220
Photographic Mordant Dye Process, A New ... 20
Photographic Permanence 263
Photographs, Coloring of, by Wax Medium ... 74
Photographs from Airplanes and Balloons ... *60
Photographs on "Salted Paper". 95
Photography, Dyes in 6
Photography, Photo-Chemical Reactions in ... 109
Photometer, A New Stellar 23
Phototropy, in Crystals 80
Physical Relativity 346
Physics, Fundamental Concepts of ... 287
Physics and Crystallography, Molecular Orientations in I, 18: II, 46
Piezo-Electricity and Its Applications ... *412
Pigments in Plants, The Antarocyanin ... 2
Pile Driver, Novel *391
Pillars, Prentice 176
Pillories, *See* Stocks.
Pine-Tree Needles, Cotton Substitute from ... 96
Planes, Experiments With Tandem ... *204
Plants, The Anthrocyanin Pigments in ... 2
Plant Growth and Reproduction. 38
Plant Tags, Linen 48
Platinum, Ductility of 249
Platinum, Replacement of, in Electrolysis Apparatus 187
Platinum Substitute, A..... 32
Playertype Photo-Copying Process ... 271
Pleistocene Man of Vero, Fla... 118
Plumbago Crucibles, Using Up Old ... 243
Plywood in Airplanes 415
Poland, Anthropology of 381
Poland Naval Forces of Old.. 178
Pompeii and Saint Pierre (G. W. Cole) ... 314
Position of the Illuminant in Enlarging and Projection ... 351
Pottery, Prehistoric *377
Prentice Pillars 176
Pressure, Increasing by Electrolysis ... 102
Pressure Variation, Effect of—in Dust-Pressed Tiles 197
Principles of Diffusion and Their Analogues ... 31
Prisms, Reflecting in Place of Mirrors ... *172
Projectiles, Curious *28
Prisoner, Mentality of the War. 105
Propeller, Keeping the—Dry (M. E. Dunlap) *292
Prosthesis of the Lower Limb.. 200
"Protoactinium," a New Radio-Active Element 215
Prune Cultivation in France 21
Puley Puzzles *383

R

Radio-Activity, Radium and (C. H. Viol) .I, 194; II, 214; III, 239
Radio-Telephony (Craft and Colpitts) I, *245; II, *268; III, *280
Radium and Radio-Activity (C. H. Viol), I, 194; II, 214; III, 239
Radium vs. Meso-Thorium in Luminous Paints 272
Radium-Therapy, Medico-Legal Aspects of 167
Railroads, Work of, in War.... 142
Raleigh Tercentenary, The 39
Rat Pest, The 21
Rations, Balanced, from Restricted Sources 202
Rectifier, Alternating Current, How Made *76
Rectifiers, Big Mercury-Vapor.. 123
Reefs, Fringing, of the Philippine Islands (W. M. Davis). 58
Refractory, Zirconia as 54
Refractory Materials and the Glass Industry 329
Relation of Light to Health, The 4
Relativity, On the Essence of Physical 151
Relativity, Physical (de Tunzelman) 346
Rennets, Animal and Vegetable (F. Faidean) *285
Resins of Australia, The Grass Tree 137
Resistance of Ships 75
Respirators, Gas Masks, and Oxygen Breathing Apparatus, Industrial Use of 254
Revegetation 302
Rhinocerous, White, Finest Specimens of in Africa *53
Rock Paintings by Bushmen ... 62
Roquefort Cheese, Bacterial Flora of 75
Rubber as a Colloid (D. F. Twiss) 306
Rubber Substitute from German Plants 237
Rubber, Synthetic 358
Rubber, Test for Synthetic ... 56
Rubber, Vulcanization of, at Constant and Increasing Temperatures 317
Rubber-Insulated Wires, Substitute for 307
Rubber-Seed Oil 21
Russia, Races of (A. Hrdlicka) I, *364; II, 378
Rutile 119

S

Safety at Sea, Scientific Signalling and (J. Joly) *334
Safety of the Alternating Current Crane 62
Sahara, Agricultural Possibilities of 297
Salmon Fishing by Machinery. *104
"Salted Paper Process," Described 95
Salvage Work in New York Harbor *232
Scoop Conveyor, Portable *264
Sea Floor, Productivity of 201
Sea Lions and the Fishery Industries (C. H. Townsend).. 328
Sediments, Study of—Aid to Geologist 183
Seeds, Oil in—Determination of 155
Seed Germination, Influence of Aluminum Ions on (J. Stoklass, etc.) 318
Selection, Rôle of, in Evolution I, 66; II, 90
Selenium Cell Used in Orienting Mechanism *376
Sensation, Curious Case of Absence of 127
Serbia, German Mining Operations in 317
Sewage Disposal by Dilution ... 27
Shell Builders (Conchology) (R. W. Shufeldt).... I, *308; II, *348 III, *380
Ship and Cargo in One *383
Ships, Manufactured or "Fabricated" *130
Ship's Form and Stream Line Motions *185
Ship Repairing, New Method of. 144
Ship, Trim of 127
Shipment, Packing Goods for.. 138
Shock in Hydraulic Systems ... 84
Shrew, Hero *84
Signalling, Scientific and Safety at Sea (J. Joly) *334
Significance of Dreams (E. Rignano) 326
Silks, Differentiation of Natural and Artificial 136
Skins, Liquid, Breaking of... 72
Silks, Artificial, Cross-Sections of 96
Silk, Formation of the Thread in the Spinning of Artificial . 14
Silks, A Wonderful Exhibition of Old French 37
Skoda Works, Austrian Munition Factory 115
Slag, Widening Demand for Blast-Furnace 251
Soap, War Substitutes for, in Germany 53
Solutions, How to Cork Up 150
Some Native Industries of German Cameroon *344
Some Peculiar Thermoelectric Effects 43
Sound, the Perception of ...173, 235
South America, Camelidae of.. *120
Soy Bean Milk 233
Spark Gaps 198
Sparking Coil, Improved 358
Sparking Plugs, Construction and Use 198
Sparrowhawk, Habits of the .. 10
Spectroscopy and Dissociation . 48
Spectrum Analysis and Atomic Structure 382
Spectrum Colors, Newton and the *236
Speech, Analysis of the Mechanism of *221
Sphagnum Moss 48
Spider's Webs, Fishing With.. *148
Spiritualism, Philosophy and.. 345
Spitsbergen, Minerals of 126
Spraying Metals, New Process of 29
Spruce, Sitka—Emergency Seasoning *404
Starch, Nature's Factories for Sugar and 223
Stars, Light-Giving Power of.. *395
Steamers, The Duch Keel in Sea-Going 16
Steel for Reconstruction *20
Steel, Manganese Alloys in Open-Hearth Practice (S. L. Hoyt) 282; 302
Steel, Soft, Effect of Phosphorus on the Qualities of 54
Steel, Warping of, Through Repented Quenching 71
Stellar Evolution (W. D. MacMillan) *322
Stellar Photometer, A New..... 23
Stocks and Pillories of Old England *132
Stone, Artificial, from Mica and Clay 195
Stone Age Dwellers in Arizona Today *324
Strontium in Copper Castings.. 173
Substitutes, Industrial, in Germany 336
Sugar from Several Points of View 154
Sugar and Starch, Nature's Factories for 223
Sulphuric Acid, Manufacture of by Chamber Process 370
Sun, Angular Movements 413
Sun, Magnetic Field of 293
Super-Conductors, Undamped Currents in 71
Supermagic Square, The 34... *44
Surveying and Mapping from Airplanes 386

T

Tabanuco Gum or Elemi..... 201
Tags, Linen Plant 48
Tamil Speech, Antiquity of (J. Lazarus) 238
Telephony. *See also* Radio-Telephony
Temper, Removing from Hardened Steel 112
Temperature, High, in Engineering 232
Temperatures, Measuring Fluctuating 52
Terra-Cotta, Pinholing and Peeling on 155
Tests for Trainmen in Germany. 307
Textiles, Action of Laundry Reagents on 123
Textile Fibers in Germany 217
Thermoelectric Effects, Some Peculiar 43
Thimbles, Scarcity of 53
Things That Might Be Used (J. Waddell) 298
Tiles, Effect of Pressure Variation in Dust-Pressed 197
Tin Mining in the Dutch Indies. 383
Titanium 119
Tonka Bean, and Cumarin 78
Transatlantic Flight, Winds and 396
Transportation, The Canal in the Problem of *168
Transportation in Miss. Valley, Economics of *406
Transportation on the Magdalena River, Colombia *88
Transvaal, Rock Paintings in.. 62
Tree Surgery *200
Trim of Ships 127
Two-Cycle Paraffin Oil Engine.. 327

U

Ultra-Violet Energy (Luckiesh). 242
Ultra-Violet, Rôle of in Chemical Reaction 208
Ultra-Violet Rays, Action of, on Sugar-Cane, Pineapple, and Banana in Hawaii (T. Tsuji). 327
Uniformity in Aerographic Records *15
Upper-Air Currents, Effects of Hurricanes on 189
Uses, New, for Some Raw Products 71

V

Vacua, High, and Their Measurement 278
Vegetable Oil Industry of Japan. 229
Venezuela, The Macoa Indians of ... I, *8; II, *24; III, *40
Verniform Appendix in the Woubat 105
Vibration, Mechanila, Musical and Electrical 5
Vision, Threshold of 285
Vitamines 62
Volcanic Blasts, Dynamic Heating of Air as a Cause of Hot (G. W. Cole) 314
Vulcanization Without Sulphur by Ostromyslenski's Method. 29

W

Wall-Paper, Manufacture of ... *184
Walnut, the Time to Cut 16
Wasps and Their Ways, Social. *196
Wasp, The Tree 14
Waste Products, Methods of Recalmation 103
Water, Color of... I, 374; II, 393; III, 410
Water for an Army..... *36
Water Power in California (Palmer) *260
Weights, Ancient Trade—of the East 237
Weights, Standard 87
Weimarn, Dispersoidology and the Theory of von 182
Welding, Electric, Modern..... 143
Welding, Electric, for Shipbuilding 79
Wind Circulation of the Globe.. 217
Winds and Atlantic Flight.... 413
Wombat, Appendix in 105
World Language 99
World, How Old Is (McNairn). 255

Z

Zinc and Aluminum Alloys ... 367
Zinc Pole, Sign of, in a Battery. 53
Zircon, New Uses for 391
Zirconia, as a Refractory 54

919

48
148
345
126

29

404

222
395

16
*20

302

54

71

322
23

132

195

324
173

336

154

223

370
413
293

71
*44

386

201
48

258

112

232

52

155
367

123
217

43
53

208

197
383
119
78

39

*168

*406

*88
62
*200
127
327

242

208

327

*15

189

71

278
229

*40

105

5
285
62

314

29

*184
16
*196
14

103
393
410
*36

*260

237
87

182
143

79
217
413
105
99
255

267
53
391
54